# Wearable Humidifier for Dry Eyes

By

NUR HAEDZERLIN BT MD. NOOR

14883

Dissertation submitted in partial of

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(Electrical and Electronic)

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Universiti Teknologi PETRONAS,

Bandar Seri Iskandar,

31750 Tronoh,

Perak Darul Ridzuan.

# CERTIFICATION OF APPROVAL

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A project dissertation submitted to

Electrical and Electronic Engineering Program

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(ELECTRICAL AND ELECTRONIC)

Approved by,

(AP Dr. Tang Tong Boon)

UNIVERSITI TEKNOLOGI PETRONAS

TRONOH, PERAK

JANUARY 2015

# CERTIFICATION OF ORIGINALITY

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

NUR HAEDZERLIN BT MD NOOR

# ABSTRACT

Dry eyes disease has become one of the common eye-related problems which happen due to deficiency in tear production. There are many factors contributing to this disease such as ocular surface and tear film problem, age and gender, indoor environment, and computer vision syndrome (CVS). There are eye supplements available for dry eye treatment and according to a research, moisturizing the area of the eyes proved to be very effective in reducing the symptoms. However, these eye supplements need to be applied regularly in order to preserve its effectiveness. It is such a troublesome for the older people as they might suffer from wear and shaky hand movement. Therefore, the objective of this project is to understand more about dry eye disease and come out with a wearable humidifier for the eyes. It is an electronic eyewear, where it can self-regulate according to the indoor relative humidity which then able to produce mist particles that can increase small area humidity level in proximity to the eye. This thesis focusing more on developing possible design concept based on the literature reviews and the development of electrical module for the eyewear. The electrical module is designed with integrated system comprises of humidity and temperature sensors, micro peristaltic pump, ultrasonic transducer and Arduino as the base controller. Furthermore, with the wearable eye humidifier prototype model, testing is carried out to measure relative humidity levels in a small enclose area before and after humidification process. From the testing it is found out that the relative humidity level increased by 30% from its initial value. Thus, the prototype indeed able to increase small area humidity level and from this finding as well, it can provide a better solution for dry eye disease.

# ACKNOWLEDGEMENT

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# CHAPTER 1

# INTRODUCTION

## 1.1 Background of Study

Human eyes are one of the human organs that provide the ability for human to see things. Human eyes are very sensitive to its surrounding and easily affected by harmful bacteria and viruses. Nowadays, there are many diseases that are related to human eyes and one of it is dry eye disease. In medical term, dry eye is known as keratoconjunctivitis sicca. This condition typically happens due to deficiency in the quantity and quality of natural tears produced by the patient's eye [1]. Natural tears can protect the eyes from any irritation and keep them moisturized and lubricated all day long. Referring to an article written by Davison and Paulson [2], people suffering from dry eyes normally will experience constant pain from the eye irritation, which includes a sandy and gritty sensation that can result in scaring and ulceration of the cornea if it is left untreated. In extreme severe cases, it will lead to partial or total loss of vision.

Precorneal tear film (PTF) shown in Figure 1 below is one of the component of the ocular surface. Schwebel [1] states that tear film consist of three main layers. The first outer layer is the lipid layer. It is produced by meibomian glad which is located along the eyelid margin. The middle layer would be the aqueous layer secreted by lacrimal gland. Next is the innermost layer which is the mucin layer produced by the goblet cells scattered around the conjunctiva epithelium. Experiencing problem with any three of this percorneal tear film indeed can result in dry, gritty feeling and burning of the eyes.

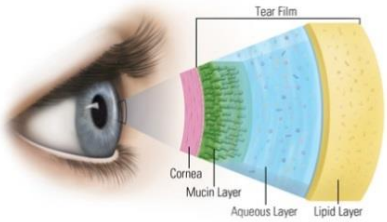



Figure 1 Percorneal Tear Film structure

Eventually, there are many causes associated with dry eye problem. Pong [3] in his article point out that, the causes of dry eyes can be divided into two sections which is the primary and secondary section. Primary causes are related to the internal problem of the eye itself like abnormal tear film, lacrimal deficiency and so on. Meanwhile, secondary causes will be closely related to the environment (low humidity), age and gender, hormonal, medication and long hours in front of the computer. Dry eyes normally occurred in adult population as it is estimated that nearly 75% of man and women over the age of 65 experience dry eye disease.

Currently there is no cure for dry eye disease. However, there are verities of treatments that are designed to reduce the irritation and discomfort cause by dry eye conditions. The treatment varies with the severity of the diseases. For slightly dry eyes, the use of artificial tear supplement in form for eye drop should be sufficient, and it needs to be applied regularly. For those who suffer from moderate dry eyes, the use of gels is recommended as these gels will last longer than the eye drop. Finally, patient with severe dry eye problem might need to use lubricant ointments or undergo minor surgery to occlude the tear duct [4].

Apart from the treatments mentioned above, there are also other ways to heal such dry eyes. Ogura [5] mention that moistening the air surrounding the eyes is found to be very effective in healing the symptom of dry eyes. Therefore, the purpose of this study is to fully understand about the dry eye disease and come out with an electronic eyewear compromise of sensors and ultrasonic mist generator (wearable humidifier) that can preserve the moisture of the eyes for a longer period of time. This eyewear will create a microenvironment within the user eyes. It will be able to self-regulate according to the surrounding (indoor environment) relative humidity. In the microenvironment, these two aspects (humidity and temperature) will be controlled accordingly in order to provide comfort to the user. Besides that, with this invention, treatment for dry eyes will be much more affordable and everyone can own it.

## 1.2 Problem Statement

Dry eye is a common disease happens especially in older adults. Dry eye bring discomfort to the eye and can result in loss of productivity, concentration and unhappiness in sufferers. There are many treatments suggested by the optometrist, in maintaining the health of the eyes. The most common treatments are applying artificial tear supplement, gels and ointment to the eyes. Problem arises when the eye supplement need to be applied regularly to preserve its effectiveness. It is such a troublesome for the elderly patients as they might suffer from weak hand movement. Furthermore, people tend to forget to apply these eye supplements when they are busy with their daily routine and not to forget these types of treatments are also very expensive.

Therefore, there is a need to invent a device for treating dry eye that is easy to use, user-friendly, comfortable, affordable, safe to wear and at the same time can promote healthy eyes.

## 1.3 Objectives

The objectives of this project are:

i. To study and understand about the dry eye syndrome.
ii. To evaluate and analyze the water mist mechanism
iii. To study the current invention in treating dry eye disease
iv. To develop an eyewear that can increase humidity level around the area of the eyes

## 1.4 Scope of Study

This project will develop a working prototype model, which is an electrical module for the eyewear. This electrical module is the backbone for the development of the eyewear. Through humidification process, a moisturized microenvironment can be created within the area of the eyes. The first task in developing this project is by conducting research on the dry eye disease, factor effecting dry eyes and treatment available for dry eyes. All of this information is useful for the development of the model. Next, a study and analysis has been done on ways to generate mist in application to cool down or moisturize an area. Besides that, research has also been done on the current invention on treatment of dry eyes syndrome. Ideas and designs for the eyewear are then generated to select the best design for the project.

## 1.5 Report Organization

This thesis consist of 5 chapter altogether. The Chapter 1 describing the background study on dry eye disease, stating the current problems arises that relates to the disease and the objectives as well as the scope of study for this thesis. In chapter 2 a review been done on some of literatures (research paper etc.) related causes and treatment of dry eye disease, misting mechanism and humidifier that is available in current market. Next, in Chapter 3, project activities and its timeline are briefly described. Meanwhile, Chapter 4 specifically describing about the result of the research. It is divided into 4 sub topics, which is project stages, prototype development, experiment and testing, and the future work. Last but not least, in Chapter 5 where conclusion and some recommendations are written in this chapter.

# CHAPTER 2

# LITERATURE REVIEW & THEORY

## 2.1 Dry eyes causes and treatment

A publication of DEWS report [8] has come out with an improved definition for dry eyes. The subcommittee agreed on defining dry eyes as, "*A multifactorial disease of the tears and ocular surface that results in symptoms of discomfort, visual disturbance, and tear film disability with potential damage to the ocular surface. It is accompanied by increased osmolarity of the tear film and inflammation of the ocular surface".*

According to [3,8], dry eyes syndrome can be divided into two main parts. The first one is tear deficiency of dry eyes and secondly is evaporative dry eyes. The tear deficiency type is divided further into two parts known as Sjogren Syndrome dry eyes and Non-Sjogren Syndrome dry eyes. Both of these types are autoimmune diseases that are closely related to problem with lacrimal gland and salivary gland. Meanwhile, for evaporative dry eyes it can be divided into meibomian glad disease (MGD), mucin deficiencies and exposure related dry eyes factors such as low blink rate and low surrounding humidity.

As mentioned in the definition above, dry eyes is a multifactorial disease, which means there are multiple factors or causes that affects the dry eyes syndrome. For this report, discussion will be done only on a few factors that contribute to dry eyes syndrome. Those factors are difficulty of ocular surface and tear film, age and gender, environment and computer vision syndrome (CVS). As mentioned by Johnson and Murphy [9], dry eye syndrome (DES) is closely associated with ocular surface disease where most DES patients facing problem with abnormalities of their tear film. Problematic tear film will cause insufficient supply of tears to the ocular surface that will then contribute to inflammation of the ocular surface.

There are many studies being done relating to Dry Eye Syndrome (DES) with age and gender. Guillon and Maissa [10] had conducted an experiment in proving that

age and gender can affect the tear film evaporation. Their experiment is conducted in 30% to 40% of air humidity. It is found out that the evaporation rate is higher in older age group as compared to younger age group and more prevalence in women. This is due to several factors which includes decreased in tear production, hormonal changes and Meibomian Gland Disorder (MGD). Meibomian gland or known as evaporative dry eyes has a strong correlation with aging. This meibomian gland located at the eyelid releases a mixture of lipid and protein on the ocular surface in order to prevent the evaporation of tears. Aging will significantly affect this secretion process which explains why older people are subjected to DES [11]. However, there are several rare cases whereby children can have DES. This issue is often overlooked by the physician. DES in children normally occurs because of some inflammatory disorder, autoimmune, lack of nutrient and so on [12].

Besides that, Dry Eye Disorder (DES) can also be affected by the indoor environment which is related to low humidity, high temperature and high air velocity [13]. These risk factors can increase water evaporation from the tear film. Wolkoff [14] mentioned that the mucous membrane of the eyes can be very dry in low humidity (10%) environment. It is also mention in [15] that, dry air is very much related to poor indoor air quality (IAQ). Meanwhile, 40% of relative humidity (RH) is healthier for the eyes compared to 30% of relative humidity. In terms of surrounding temperature, high temperature can promote instability in lipid layer of the tear film and it is observed that tear film will be more stable with low ambient temperature and high relative humidity. Apart from that, evaporation of water around the ocular surface region rapidly increased with high horizontal and downward air velocity [14].

Last factor contributing to DES will be the issue relating to Computer Vision Syndrome (CVS). Z. Yan et al. [16] define CVS as eye and vision problems that relates close distance viewing and long hour work when working with computer. CVS is a brand new syndrome. Many of computer users do not know that they are experiencing CVS. In United States it is estimated that at least 15-45 million computer users suffer different degrees and type of CVS. Dry eyes will eventually happen as the blinking rate reduces when computer users are too focusing on the computer screen. Less blinking

will result in increase of water evaporation from the tear film. Computer users must not gaze at the screen and adjust the computer monitor to a viewing angle of 15degree lower than horizontal level to avoid from getting DES [13,16].

Dry eye disease is incurable but there are treatments out there that can reduce the severity of the disease. Calonge [20] points out that most of the treatments can only conserve the patient's tears without necessarily correcting the underlying disease. The most common and widely use therapy for dry eyes is by using topical artificial tears. The main goal is to increase humidity level at the ocular surface and to improve lubrication. One thing about these artificial tears is, it contains preservatives, stabilizer and other additives which can harm the ocular surface cell if it is constantly used. Therefore, patient who need to apply artificial tears for more than 4 times per day should avoid using this treatment.

There is another method called canalicular or punctual occlusion. It is a non-pharmacological approach in treating dry eye disease. This treatment claimed that it can improve the quantity and quality of the aqueous component of the tear film and reducing symptom of dry eyes. Patients will be more comfortable and hence, reduce the need for artificial tears. Besides tear preservative method, DES patients can try to humidify their rooms and try to use moisture chamber spectacles which also proved to be very effective in reducing evaporation of tears. There are also drugs known as lacrimomimetics been used to simulate the lacrimal gland to produce tears. Apart from that, there are other treatments which are still under investigation such as tropical vitamin A, tropical autologous serum, botulinum toxin, acupuncture and antiviral agent [20].

## 2.2 Water Mist Mechanism

Nowadays, there are several different types of water mist system being used in many applications. This water mist mechanism can be applied in developing this eyewear's project.

Recent work by Farnham [17] constitutes that there is an increase in the usage of evaporative mist cooling system in urban spaces of Japan. This is due to the urban heat island problem. Therefore, Japanese placed overhead hydraulic misting nozzles at the Aichi Expo 2005 to cool down their outdoor pedestrian spaces. It managed to cool down the area as much as 2-3 Kelvin. This hydraulic misting has capability to produce droplets with average diameter below 100 microns. Santangelo [18] also point out that water-mist system had become a brand new technology that is used for varieties of application especially in fire protection and humidifying an area or surface. Water mist spray usually operates in a very high pressure condition and is able to produce relatively small droplet of water. Hence, spreading water droplets over a larger area and cooling the surrounding area via evaporation process.

Then there is another technology called electronic ultrasonic water mist. It utilizes the piezoelectric transducer that will convert electrical energy to high frequency mechanical vibrations. It operates under an ambient pressure and it is capable of producing extremely fine micron and sub-micron size water mist. Currently, this technology is being utilized in application of fire extinguishing [19]. Figure 2 below shows the ultrasonic water mist used in fire extinguishing.

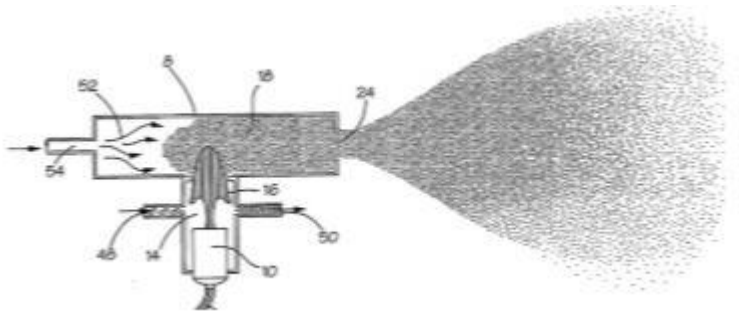



Figure 2 Ultrasonic water mists

## 2.3 Wearable humidifier available in the market

Presently, with technological advancement, chronic diseases such as dry eyes disease certainly can be treated and cured. There are many wearable humidifiers available in current market that is specifically for humidification of eyes. Most of the inventions are in the form of eyewear and it is aimed to treat dry eyes problem. Although all of these products function in the same way, their inventors managed to come out with their own unique ideas in preserving the moisture of the eyes. Hence, help to treat dry eye syndrome effectively. All of the inventions are describe below.

In Figure 3 below, an eye moistening device invented by [5] compromises of eyewear that includes the side covers to protect both of the left and right sides of the eyes. It is being equipped with detachable eye-moistening means that it can be placed on the inner side of these side covers. This eye-moistening means are made out of porous elastic or pliable material which makes it adaptable to be soaked with water or medicine. The water or medicine then will slowly evaporate to the eyes when it is place on one's face.

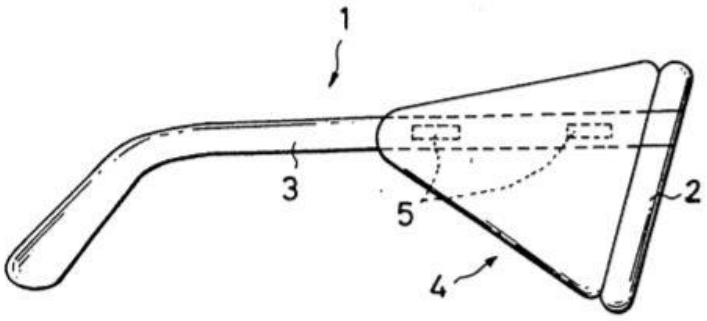



Figure 3 An eye-moistening device

The second invention [4] for treatment of dry eyes uses a biodegradable polymer capsules. It uses a system called plug system that consists of solid, porous or hollow microcapsules. They are biodegradable polymer. These capsules shown in Figure 4 below are stored in the form of powder. It can be suspended in a solution or let it dispersed in an ointment or a gel. This treating agent is placed in a polymer shell or polymer sphere and it will slowly release to the eyes as the polymer degrades.

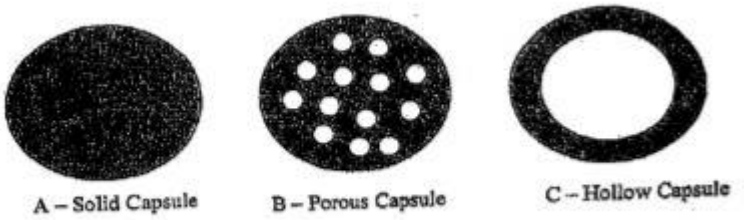



Figure 4 Biodegradable polymer capsules

Next will be an invention by [2] where the inventors had designed curved eyecups (12) with an interior cavity that will provide treatment for the eyes when this eyewear is worn. Removable moisture pad (26) is place on the sidewall surface of each interior cavity. This moisture pad can be soaked with different type of liquid (water or medicine) and it has the capability to change its temperature (hot or cold) according to the user preferences. This eyewear is designed with strap (20) and fasteners (22) to make sure it fits the user. This remarkable invention is shown in Figure 5 below.

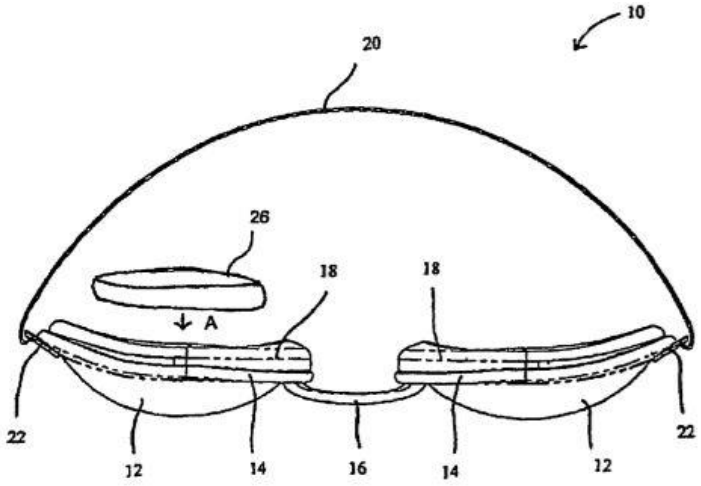



Figure 5 Eyewear with removable moisture pad

Then there is another invention by [1], where she had created three different look of eyewear. All of these eye wears are equipped with moisture reservoir and it is designed to fully enclose the area of the eyes. Figure 6 shows a sleeping mask where the mask itself is made out of moisture permeable and flexible material. The moisture from the mask will then be absorbed by the eyes. In daytime, user can change to eyewear in Figure 7 where it uses transparent lens that also incorporate a moisture chamber at the

side cover of the eyewear. The inventor added more features in her invention by cooperating it into a hat shown in Figure 8. A moisture chamber is attached to the upper part of the hat. This is where it can provide high humidity environment for the eyes and provide enough protection against evaporation due to air movement.

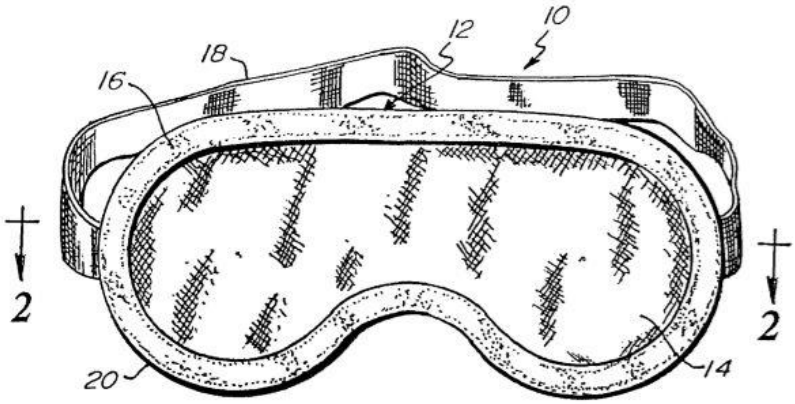



Figure 6 Sleeping Mask

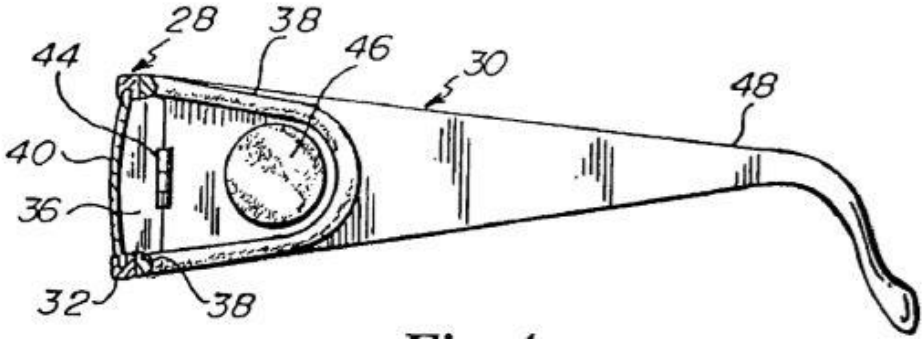



Figure 7 Eyewear with transparent lens

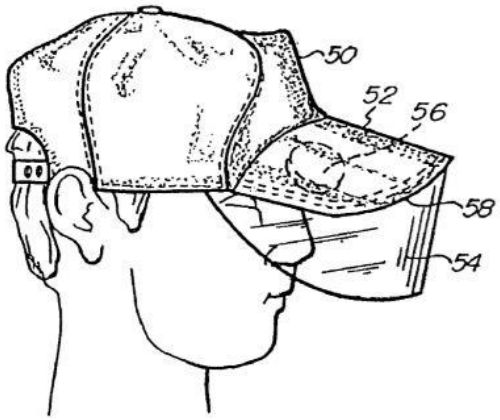



Figure 8 Moisture chamber attached on a hat

The fifth invention in treating dry eye syndrome is invented by [6]. This eyewear in Figure 9 is designed to at least partially enclose the area of the eyes from the surrounding environment. It consists of frame, leans and seal. Humidity as well as temperature is being elevated in the area about the eyes. Furthermore, the seal is removable and it can easily be attached to other eyeglasses or even sunglasses. A filter known as HEPA filter is being used together with the seal.

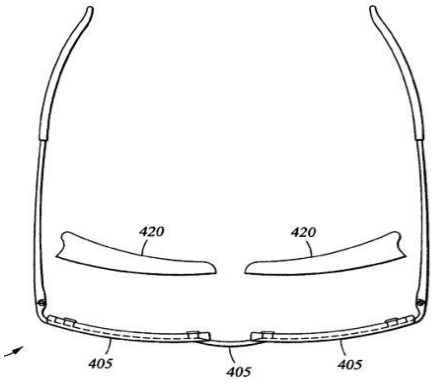



Figure 9 Eyewear for Dry eyes

The sixth invention will be from [7] that invented an eyewear for relief of computer vision syndrome (CVS). CVS occurs due to long hours of staring and glancing at the monitor. High amount of light reflected into the eyes can cause eye problem. Therefore, this invention is designed to block some light from entering the eye. It has its own housing surrounding the user's face and a forehead portion. The interior as well as the exterior surface of the housing are made out of opaque material. The invention can be illustrated in Figure 10 below.

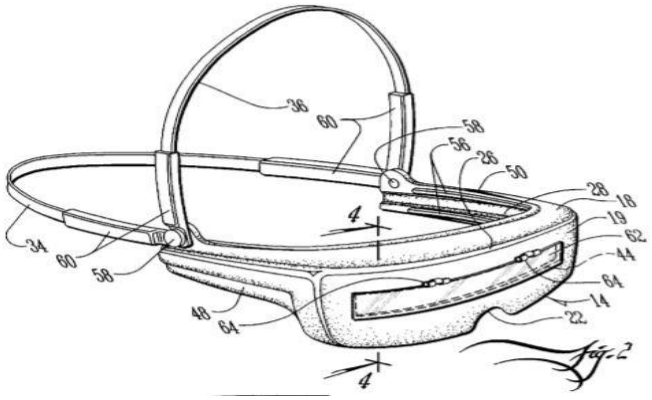



Figure 10 Eyewear to reduce CVS

The next invention is from [21], he invented a hands free eye treating/watering system that can be used with computer or any other system that can selectively emits eye supplements in the direction of the eyes in reducing the dryness or discomfort of the eyes. The system is shown in the Figure 11 below. The watering system (10) is coupled to the processor of the computer by a device called computer usage detection logic (60). It is equipped with container containing lacrimal glands vaporized liquid (80) but other liquid may also be used. This system also comes with control valve (72) couple with a timer circuit (74). The user (30) may adjust the setting of the timer to control the water been release from the valve.

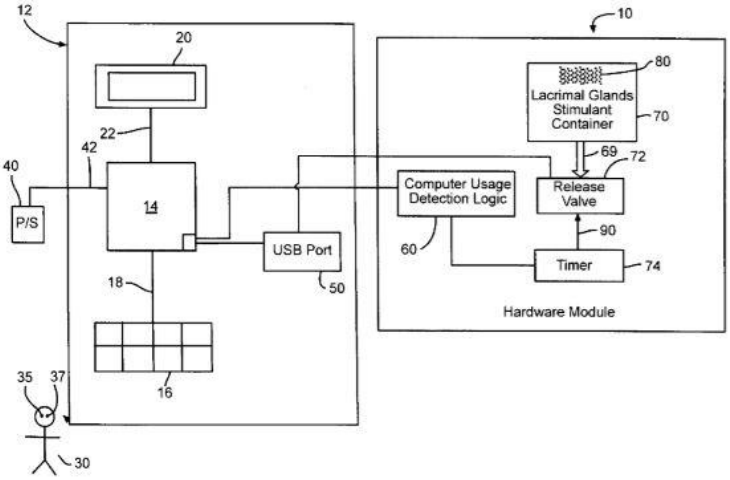



Figure 11 Hand's free system for dry eye treatment

The last invention will be a moisture retention eyewear developed by 7eye (Pam-Optyx, Inc. Pleasanton, CA, USA). It is one of the eyewear that is commercially available in the market now. A research had been done by [22] to evaluate the suitability of this eyewear shown in Figure 12, in treating evaporative dry eye. The researchers found out that, there was a positive improvement in dry eye symptoms after using moisture retention eyewear after 3 months. The eyewear is designed with removable air shield made out of foam with rugged. The non-air permeable construction made it suitable to retain moisture by limiting the air flow in the area of the eyes. Apart from that, it has adjustable frames that can provide good fitting to the users.

Figure 12 Moisture Retention Eyewear

All of mentioned inventions above are summarized in Table 1 below. This project design concept is inspired by these researches.

Table 1 Summary on available eyewear design

| No | Author (s) | Design Approach |
|---|---|---|
| 1. | Ogura (1994) | • Detachable eye-moistening<br>• Place on the inner side of these side covers<br>• Made out of porous elastic or pliable material<br>• Soaked with water or medicine<br>• Slowly evaporate to the eyes |
| 2. | El-Sherif et al (2003) | • Biodegradable polymer capsules<br>• Stored in the form of powder<br>• Suspended in a solution or let it dispersed in an ointment or a gel<br>• Place in a polymer shell or polymer sphere<br>• Releases to the eyes as the polymer degrades |
| 3. | Davison et al (2007) | • Curved eyecups with an interior cavity<br>• Removable moisture pad is place on the sidewall surface<br>• Soaked with water/ medicine<br>• Capability to change its temperature (hot or cold) |

| | | |
|---|---|---|
| 4. | Schwebel (2006) | • 3 designs approach :<br>• Sleeping mask, contain moisture reservoir.<br>• Transparent lens that incorporate a moisture chamber<br>• Moisture chamber is attached to the upper part of the cap |
| 5. | Yee (2007) | • Partially enclose the area of the eye<br>• Removable seal, attached to other glasses<br>• In cooperate HEPA filter |
| 6. | Khulusi (2002) | • Housing surrounding the user's face and a forehead portion<br>• Made out of opaque material<br>• Block some light from entering the eye |
| 7. | Abousleiman (2014) | • Hands free eye treating/watering system.<br>• Coupled to the processer of the computer.<br>• Emits eye supplements in the direction of the eyes and the users can control the timer by manually adjusting the timer. |
| 8. | S. Wadhuthantri et al. (2014) | • Research done on suitability of moisture retention eyewear developed by 7eye in reducing the evaporative dry eye.<br>• The eyewear indeed able to reduce dry eye after using it for 3 months.<br>• It has removable air shield<br>• Non-air permeable construction<br>• In cooperating adjustable frames good for fitting |

Based on the inventions mentioned above, most of the inventors choose to design an eyewear that is very comprehensive and user-friendly. The eyewear is compatible with user's daily activities. It gives comfort as well as therapeutic agent in reducing the dry eye symptoms. Most of the eyewear uses the usage of lens as an agent that will react directly to the eyes. Only one inventor, develop a hand's free electronic system which is more precise as it is designed with timer . Therefore, this design concept will incorporate both specifications, hand's free electronic system with suitable lens for an eyewear.

This project still maintains the same objective as others which is inventing an eyewear to reduce the symptoms of dry eyes. This electronic eyewear has the capability to generate mist (smaller water drops) which then can moisturize small area around the eyes. It is an integrated system which comprises of two sensors (humidity and temperature sensors), ultrasonic transducer, micro pumps and Arduino as the base microcontroller. It is an eyewear that can provide response to the indoor relative humidity accordingly. If the indoor air condition is not suitable for the eyes, mist will be generated. Hence, reduce the dry eye's symptoms.

# CHAPTER 3

# METHODOLOGY

## 3.1 Project Activities

Below are the current plan project activities for this project:

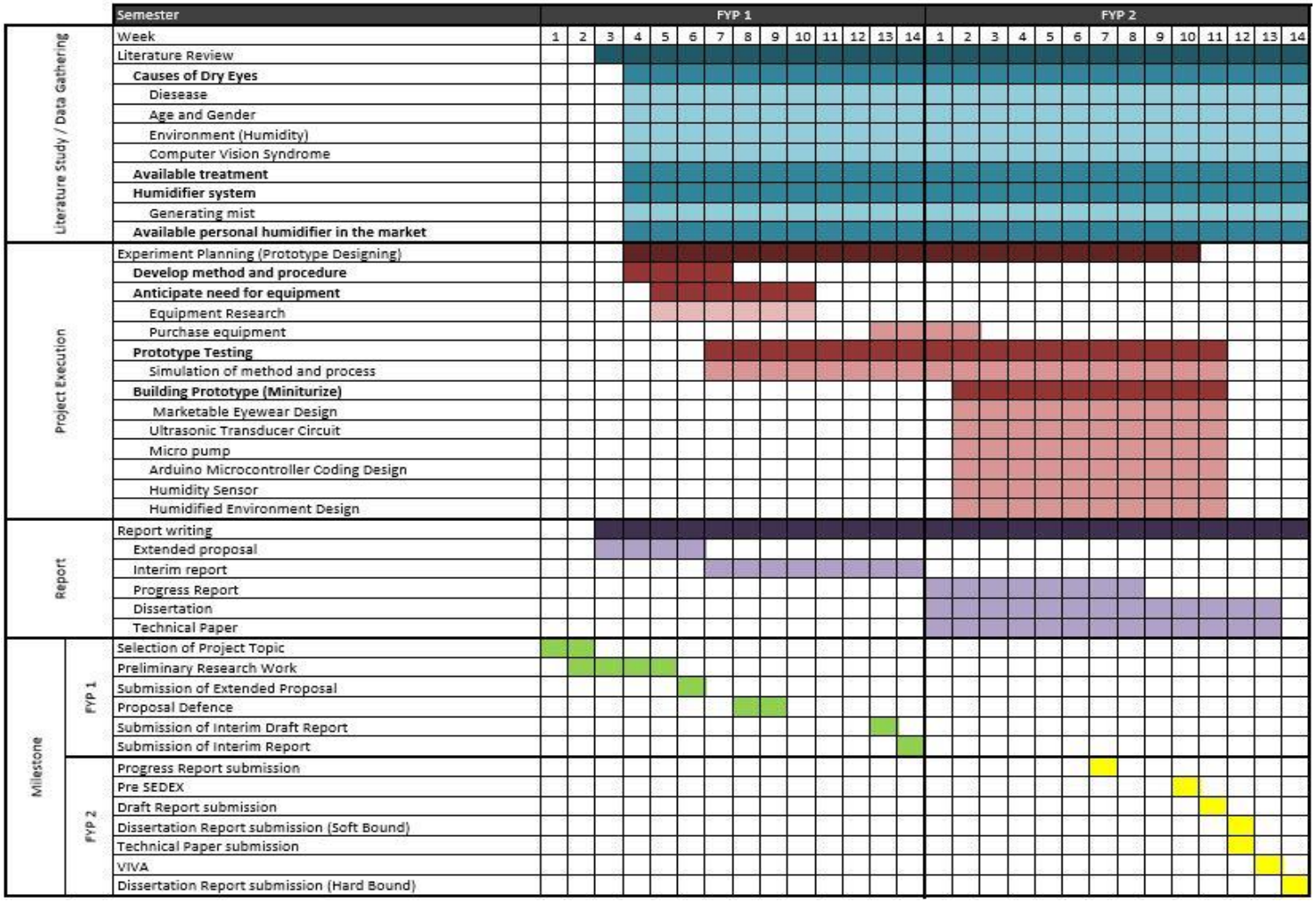
## 3.2 Tools and Software

The Table 2 below shows, the overall function for all the tools as well as software used in the development of this project and all the datasheets are attached in Appendices.

Table 2 Tools and Software use for this project

| No | Tools and Software | Model | Manufacturer | Function |
|---|---|---|---|---|
| 1. | Ultrasonic Transducer | M2313500 | S. Square Enterprise Company Limited Pro Wave Electronic Co. | Converting large water particles into atomize size of water (mist) for humidification process. |
| 2. | Micro Peristaltic Pump | RP-TX Series | Takasago Electric,Inc | To control the flow of water |
| 3. | Digital Output Relative Humidity & Temperature Sensor | DHT22 (AM2303) | Aosong (Guangzhou) Elctronics Co., Ltd | To sense the changes in air humidity and trigger pump to flow out water droplet for the next process. |
| 5. | Arduino Microcontroller | UNO | Arduino | To control all the sensors and the timing between each trigger. |
| 6. | Arduino Programming Software (Arduino Ide) | - | Arduino | Programming software for Arduino Microcontroller |
| 8. | LT Spice Software | - | Linear Technology | For simulation of design circuit |
| 9. | Eagle Software | - | Cadsoft | Designing Printed Circuit Board (PCB) |

## 3.3 Project timeline

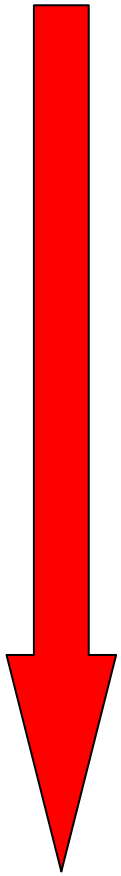


### 3.4 Key Milestone

Below is the Key Milestone for this project,

Table 3 Project's Key Milestone

| TASK | DATE | WEEKS | REMARKS |
|---|---|---|---|
| Project Work | 12/01/2015 – 22/03/2015 | 1-10 | DONE |
| Submission of Progress Report | 04/03/2015 | 8 | DONE |
| Pre-SEDEX | 16/03/2015 - 22/03/2015 | 10 | DONE |
| Submission of Final Report Draft | 23/03/2015 – 29/03/2015 | 11 | DONE |
| Submission of Dissertation (Soft Bound) | 30/03/2014- 14/04/2015 | 12 | DONE |
| Submission of Technical Paper | 30/03/2014- 14/04/2015 | 12 | DONE |
| Viva | 06/04/2015- 10/04/2015 | 13 | DONE |
| Submission of Dissertation (Hard Bound) | 13/04/2015 | 14 | DONE |



# CHAPTER 4

# RESULT AND DISCUSSION

## 4.1 Project Stages

This wearable eye humidifier project is breakdown into stages in archiving a working prototype. In each stage, experiment as well as testing is done to determine the best design for the project. Once the project is completed, all the project stages are integrated to develop a working prototype of this wearable eye humidifier. The breakdown stages of the project are as follows:

i. Micro Peristaltic Pump and DC Motor Driver
ii. Temperature and Humidity Sensor
iii. Voltage Amplifier Circuit Design (NPN Transistor)
iv. Ultrasonic Transducer and Driver
v. Arduino UNO Microcontroller Coding Design

### 4.1.1 Micro Peristaltic Pump and DC Motor Driver

Micro peristaltic pump (RP-TX Series) in Figure 11 is one of the most important elements of the project as it acts as water pump for the misting process. This water pump has the world's lowest level of flow for a peristaltic pump on the market which is 0.1-40$\boldsymbol{\mu}$l/min. It operates as stepper motor with more than 30kPa pump pressure. It is driven by a DC motor driver known as DRV8834 shown in Figure 12 below. It is a flexible motor driver equip with two H-bridge drivers and it capable of driving two DC motors or one stepper motor. Besides that, it is a programmable driver where Arduino is utilizes in this project as the microcontroller. A complete circuit consists of these two components are constructed on the breadboard and an experiment is conducted to test out the functionality of both components. The complete circuit is shown in Figure 13 below.

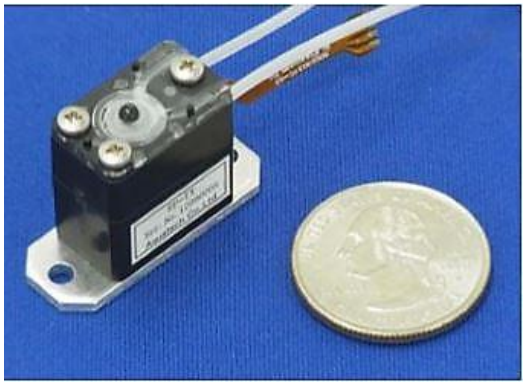


Figure 13 Micro Peristaltic Pump ( 33 x12 x 21.5mm)

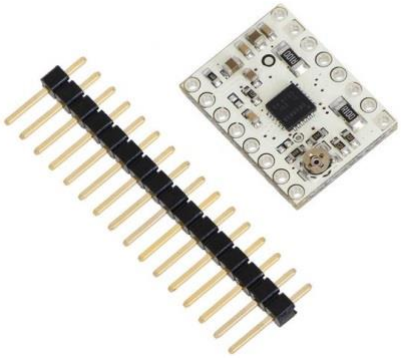


Figure 14  DC Motor Driver and Header

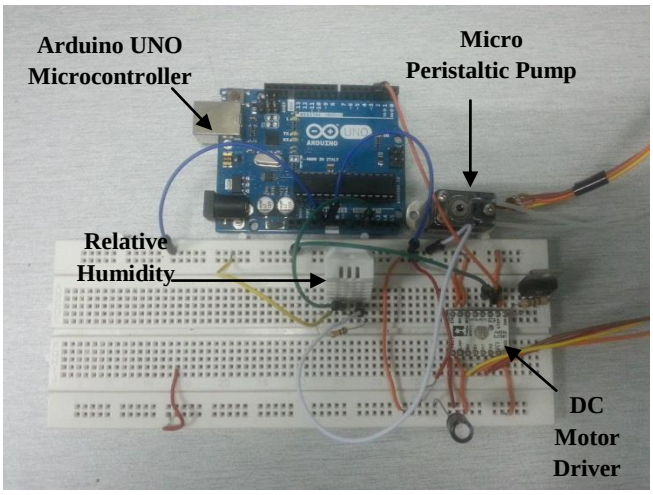



Figure 15 Test Circuit with labeled parts

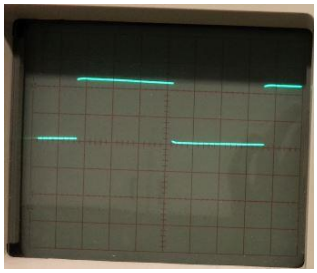
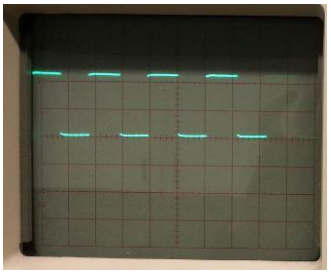
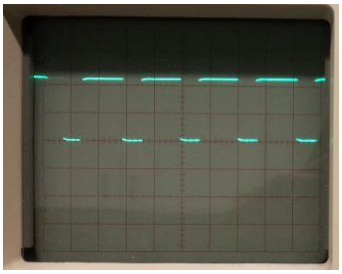
Before the experiment is conducted, the DC motor driver was programmed using C-language that will then provide required pulses to this peristaltic pump. The coding design will be explain in next section of this report. The main objective of the first experiment is to determine the best frequency in activating this water pump. The frequency supplied is directly proportional to the speed of the pump. Increasing the

frequency will as well increase the speed of the motor. A variable resistor is used in regulating the voltage supplied to the driver chip which result in changing of the frequency of the pulse produced. The frequency of output waveform is calculated from the period of the square wave by using the following mathematical formula:

$$F = \frac{1}{T}$$

Table 4 below shows the tabulation of changing of frequency in changing the speed of the pump. Frequency plays a very important role in activating this peristaltic pump. The highest frequency that can be generated is about 1kHz.

Table 4 Output Frequency Waveform

| Output Waveform | Frequency |
|---|---|
|  | 125Hz |
|  | 500Hz |
|  | 883Hz |

### 4.1.2 Temperature and Humidity Sensor

This project utilizes a sensor (DHT22) to measure the surrounding temperature as well as its relative humidity. Suitable temperature and air humidity are the two main elements in reducing dry eye disease. Both of these elements need to be constantly regulated to maintain the best temperature and air humidity within the area of the eyes. Therefore, this sensor will be able to send the required signal to the controller to activate the water pump as it senses the temperature and air humidity are both below the set point. According to the previous research done, the most suitable temperature and air humidity for the eyes are 24$^{o}$C and 30-40% respectively. DHT22 shown in Figure 14 below uses capacitive humidity sensor and a thermistor to measure the surrounding air and spits out a digital signal to the data pin. The readings are recorded every 2 seconds. In this part, an experiment was carried out to test its functionality. A complete circuit is constructed and this sensor has been programmed to ensure that it will be able to read the temperature and relative humidity.

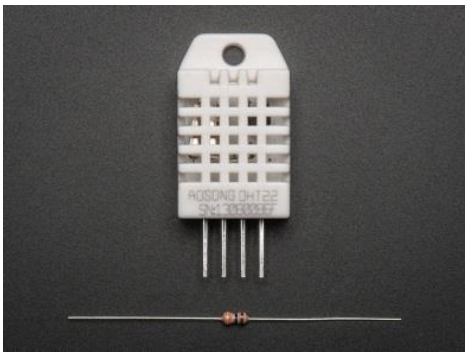


Figure 16 DHT222 and 10kOhm resistor as a reference sizing

Figure 15 below shows the testing result. Then there will be digital communication between this sensor and the water pump.

```
Humidity: 55.20 % Temperature: 34.00 *C  Heat Index: 150.19*F
Humidity: 55.10 % Temperature: 34.00 *C  Heat Index: 150.11*F
Humidity: 55.10 % Temperature: 34.00 *C  Heat Index: 150.11*F
Humidity: 54.80 % Temperature: 34.10 *C  Heat Index: 149.46*F
Humidity: 54.60 % Temperature: 34.10 *C  Heat Index: 149.29*F
Humidity: 54.40 % Temperature: 34.20 *C  Heat Index: 148.73*F
Humidity: 54.50 % Temperature: 34.20 *C  Heat Index: 148.81*F
Humidity: 54.40 % Temperature: 34.30 *C  Heat Index: 148.33*F
Humidity: 54.10 % Temperature: 34.30 *C  Heat Index: 148.08*F
Humidity: 53.50 % Temperature: 34.40 *C  Heat Index: 147.16*F
Humidity: 53.30 % Temperature: 34.40 *C  Heat Index: 146.99*F
Humidity: 53.20 % Temperature: 34.40 *C  Heat Index: 146.90*F
Humidity: 53.20 % Temperature: 34.50 *C  Heat Index: 146.51*F
Humidity: 53.10 % Temperature: 34.50 *C  Heat Index: 146.42*F
Humidity: 53.20 % Temperature: 34.60 *C  Heat Index: 146.13*F
```

Figure 17 Sensor testing result

### 4.1.3 Voltage Amplifier Circuit Design (NPN Transistor)

In archiving the desired output, sufficient power is needed in order to activate the whole system. In this prototype design, it is found out that the voltage supplied is not sufficient to power up the ultrasonic transducer circuit driver. This is where a voltage booster consists of NPN transistor play a part in archiving 5V power supply. NPN transistor in Figure 16 functions as a circuit amplifier. It can be done by using only a small amount of voltage to control the gate on a much larger supply of electricity. It is more like turning a valve to control the water supply. It can produce a stronger output signal, voltage or current that is proportional to a weaker input signal.

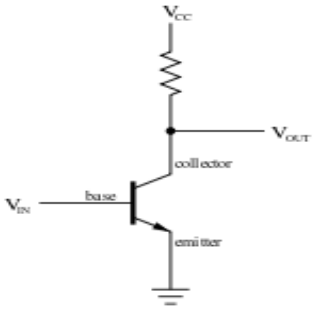



Figure 18 NPN Transistor as Voltage Amplifier

The circuit is designed and simulated using LTspice software to study the behavior as well as the output of the circuit before assemble it on the breadboard. The circuit design is shown in Figure 17 and the result can be view from Figure 18. The input voltage coming from a pulse ranging from 1-4.5V, in the result proves that by using only NPN Transistor, the voltage increase to 1-5.1V. Therefore this design can be implemented in this project.

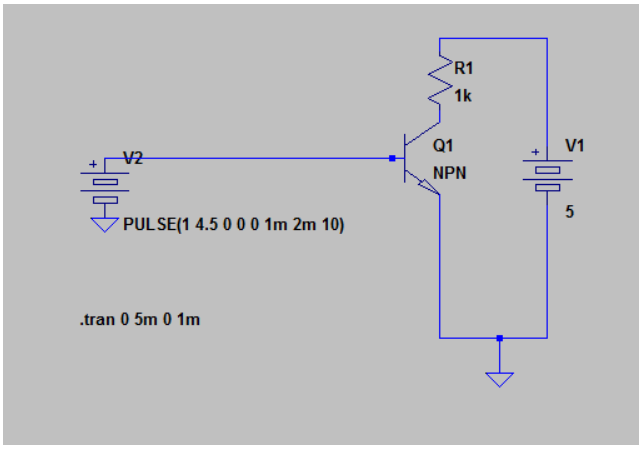



Figure 19 Simulation for Amplifier Circuit

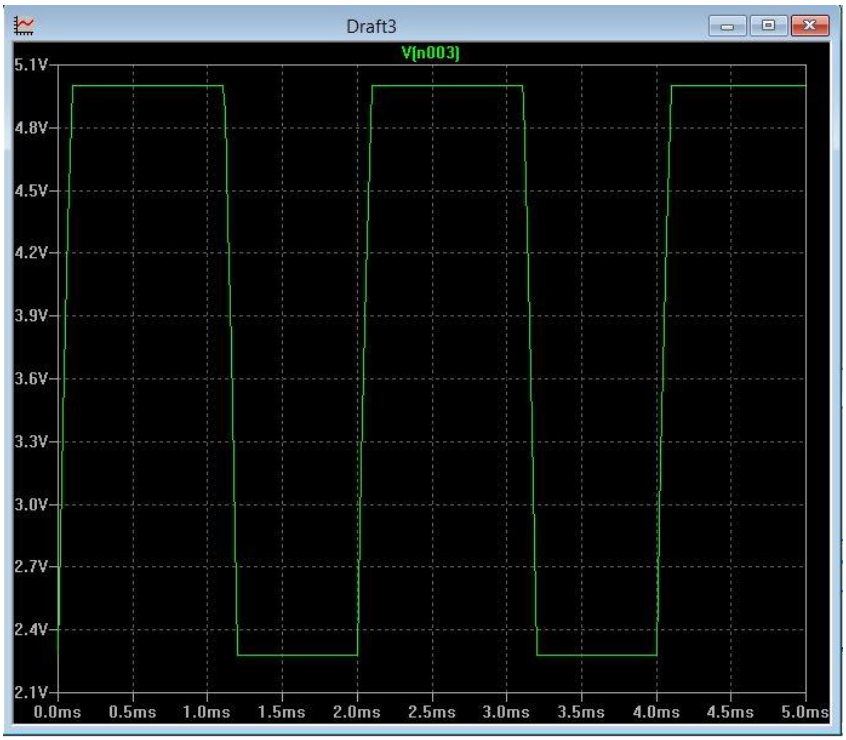



Figure 20 Simulation Result with low state and high state input of 1 – 4.5V respectively. (Duty cycle- 0.5Hz, Period 1ms)

### 4.1.4 Ultrasonic Transducer and Driver

Ultrasonic transducer is the main character in this project. It is use to covert large water particles into atomic size particles for humidification processes. According, to the research been done, it is found out that micro nozzle ultrasonic atomizing transducer in Figure 19 below able to convert water particles into mist particles effectively. It is made out of piezoelectric ceramic and metal foil. It is much more convenient that conventional ultrasonic atomizer. Besides that, a driver circuit is designed by the previous researcher where 140 kHz of resonant frequency is generated in order to activate the ultrasonic transducer. Figure 20 and Figure 21 shows the circuit and the mist particles produce by this ultrasonic transducer driver respectively.

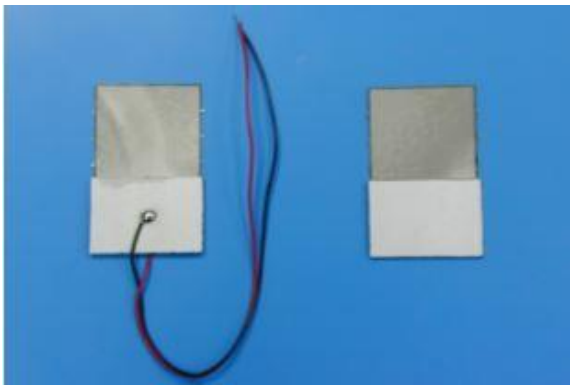


Figure 21 Ultrasonic Transducer

(29.1 x 17.3 x 1mm)

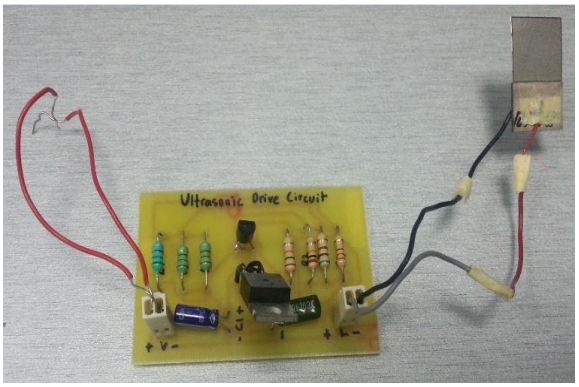



Figure 22 Ultrasonic Circuit Driver

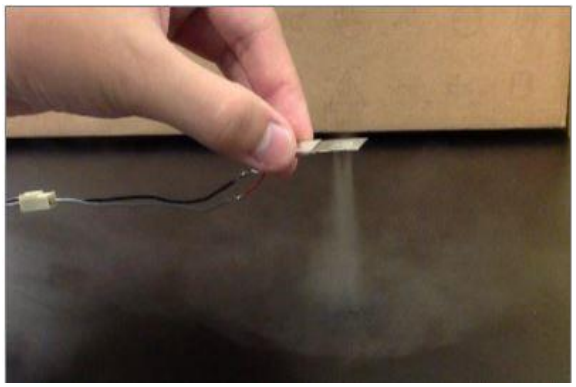


Figure 23 Misting Process with a single droplet

### 4.1.5 Arduino UNO Microcontroller Coding Design

Arduino microcontroller used in this project development is Arduino UNO. It is used to give pulses to the DC motor driver that will then activate the water pump. Besides that, the sensor utilizes this coding which enables it to read the surrounding relative humidity and temperature. Arduino is considered as a medium of communication between the sensor signal and the water pump. As the sensor reads all the required information, it send signal to the controller to activate the water pump which then supplying water to the ultrasonic plate for humidification process. Figure 22 shows the coding that allows communication between the water pump and the sensor. Testing can be done to determine the suitable set point (reference humidity and temperature) according to the condition of the room.

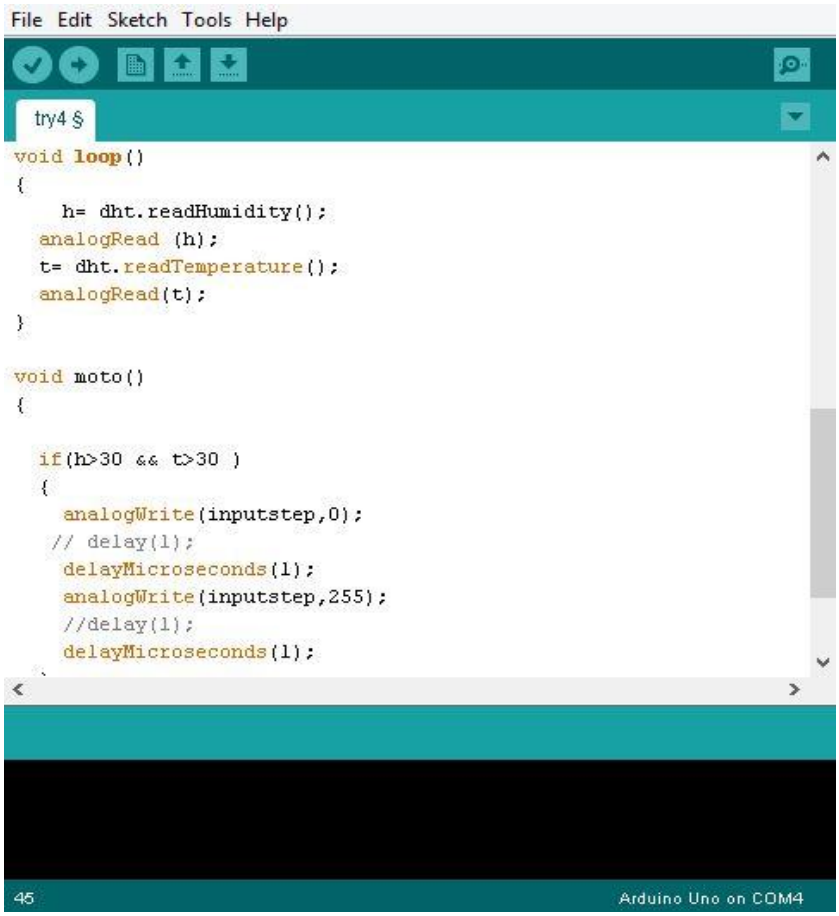



Figure 24 Sensor and Water Pump Coding

## 4.2 Prototype Development

The prototype of this wearable humidifier is developed by integrating the micro peristaltic pump and DC motor driver, temperature and humidity sensor, ultrasonic transducer driver, voltage amplifier circuit and Arduino Microcontroller developed in the project stages. All of this equipment will be in the main circuitry for the wearable humidifier. Figure 23 shows the main circuitry working prototype.

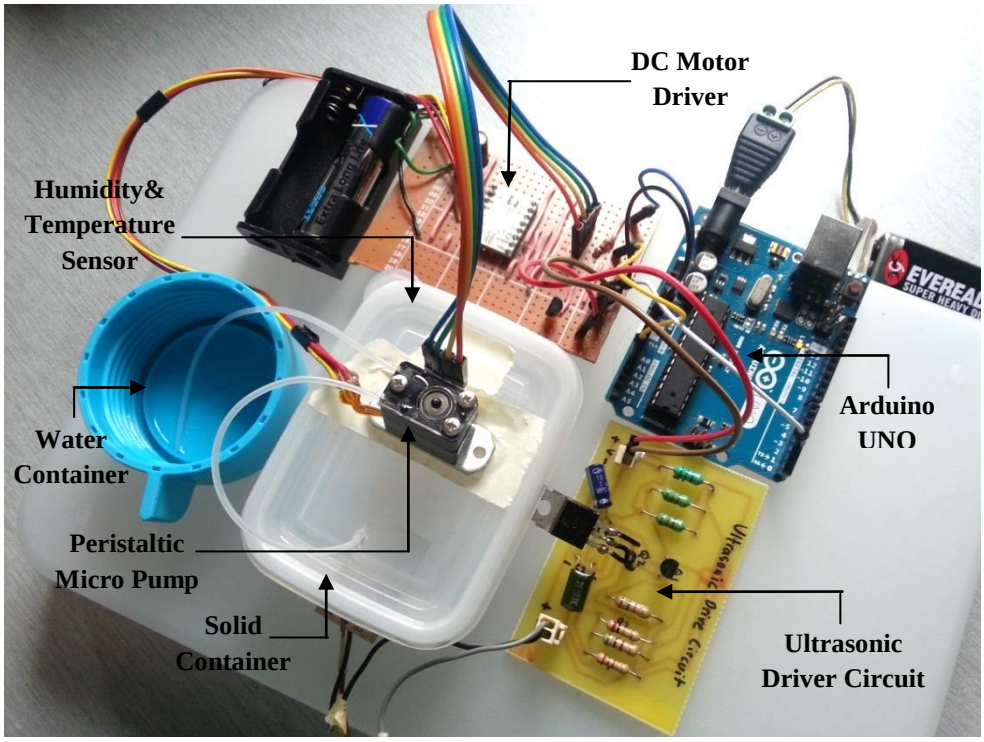



Figure 25 Eye Humidifier Main Circuitry Prototype

The prototype is tested to make sure it is functioning according to the project design. This prototype able to convert water droplets into mist particles as soon as the sensor responds to the specific relative humidity set in the program. The DC motor driver received pulses (frequency) from the microcontroller which is use to turn on the micro peristaltic pump (motor). This motor is power up by 3V voltage supply. The temperature and humidity sensor captured the surrounding air humidity and send specific signal to the microcontroller to trigger the motor. As the relative humidity reaches to the level which is less than 40%, the motor as well as the ultrasonic driver circuit will turn on. The motor pumping out the water and it will drop on the micro nozzle ultrasonic plate for misting process. If the air humidity greater than 40%, the system will remain off. The system operation can be summarized in Figure 24 below.

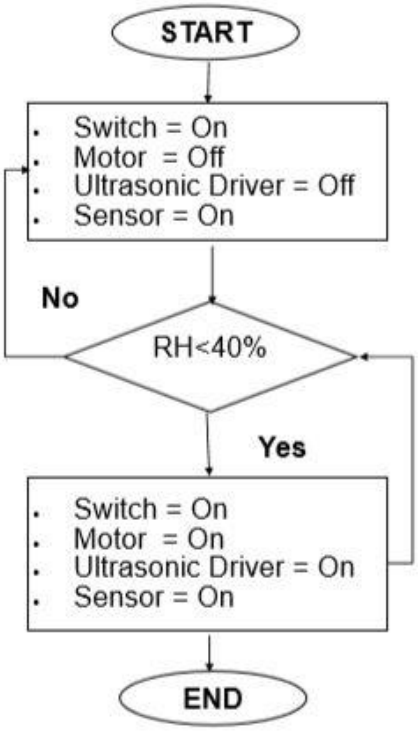



Figure 26 System Flowchart

### 4.3 Experiment and Testing

An experiment is done to test out the functionality of the prototype in moisturizing a small area. This small area represent an enclosed place like in air-condition office or inside air-craft cabin. In this experiment, the air humidity before and after humidification process inside a small container is measured and tabulated in Table 5 and Figure 25 below. The experiment is done on 22 March 2015 at 2.30PM. Speed of the motor increase to 1MHz and the data is captured every 2 minutes for 10 minutes in total. The air humidity and temperature sensor is placed inside the container to measure the changes in air humidity as time increase.

Table 5 Humidification process on small area

| Time | Before Humidification | After Humidification |
|---|---|---|
| 0 | 65.8 | 62.3 |
| 2 | 65.8 | 65.3 |
| 4 | 65.2 | 95.3 |
| 6 | 64.7 | 97.7 |
| 8 | 63.9 | 97.8 |
| 10 | 62.9 | 98.4 |

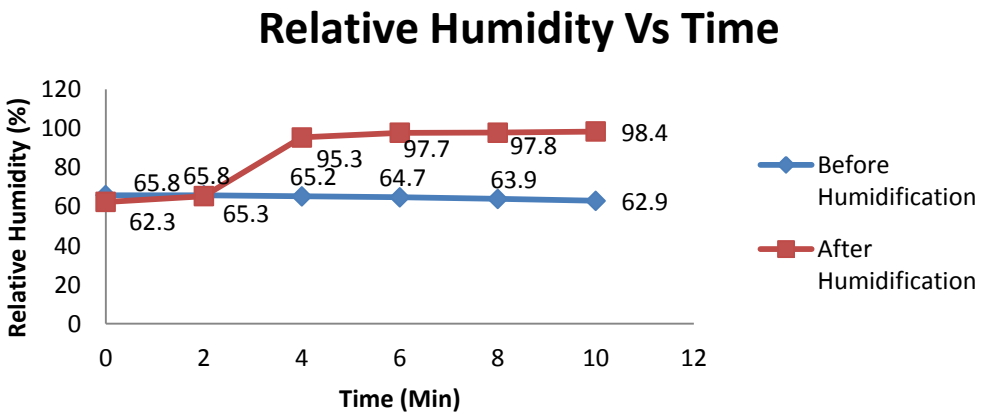



Figure 27 Graph of Relative Humidity Vs. Time

From the graph above, it is clearly shown that the relative humidity inside the solid container increase up to 30% from its initial value after humidification process. The air humidity straight away increase after 4 minutes of humidification process which is from 65.2% to 95.3%. The humidity level for this experiment is higher than 40% as the solid container is not an air tight container and it totally depend on the surrounding relative humidity. Therefore, the prototype provides the expected result as per design.

## 4.4 Future Work

The development of the wearable eye humidifier is successful with the integration of the ultrasonic transducer, drive circuit, micro peristaltic pump, temperature and humidity sensor and Arduino Microcontroller into a working prototype model. This prototype is tested and it is able to increase humidity level in a small area space which is area proximity to the eyes. The concept and ideas of wearable eye humidifier is an innovation to provide a better solution to the dry eye disease.

For now, the main circuitry (electronic part) is still quite bulky to be implemented into an eyewear. Therefore, in future, the wearable eye humidifier prototype model can be further miniaturized into a better design for commercialization purposes. The prototype can be developed into an integrated circuit which is smaller and suitable to be designed into an eyewear for everyday use. In order to make it more sophisticated, a Bluetooth module can be in cooperate in this eyewear which can be used to send real time data to the user's mobile phone. Figure 26 below shows an example of the future design for the wearable eye humidifier where all the electronic components are integrated in the eyewear and the eyewear is able to communicate with the user's mobile phone.


Figure 26 Future Concept Design for Wearable Humidifier

# CHAPTER 5

# CONCLUSION & RECOMMENDATION

The development of the wearable eye humidifier project is successfully completed. The objectives of the project are achieved whereby studies are done on dry eye disease, different humidification system and current humidification invention is made prior to the development of the wearable eye humidifier. The prototype model is tested and it is proven that the prototype able to increase the humidity level of a small area.

This paper is divided into five chapters. The first chapter mentioned about the background studies on dry eyes diseases and its relation to this project. There is also detail description on the problem statement, objectives and scope of study mentioned in this chapter. Research papers on dry eyes diseases are summarized in the second chapter. This chapter is divided into 3 parts where the first part describe the dry eyes causes and treatments, water mist mechanism in second part and the last one is on the available wearable humidifier in the current market. Chapter 3 is about the methodology for the project which consists of project activities throughout this two semester project, tools and software that will be used in the project, project timeline as well as the key milestone. Meanwhile, the prototype development and experiment and testing are being discussed in Chapter 4.

Besides that, based on the experiment and testing that had been done in determining the relative humidity inside a small area after humidification proofs that the prototype can moisturize the area. After the humidification process the relative humidity increases up to 30% from its initial value and it took only 4 minutes to moisturize the affected area.

In the future, this wearable humidifer can be improved into a better and more robust design for commerlization purposes. It can be miniturized into a integrated chip and added a bluetooh module to allow the eyewear to send real time data to the user's mobile phone. Besides that, with extended studies and research, the normal distilled water used for misting process can be replaced by eye supplements which can deliberatly improves the health of the eyes.

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# APPENDICES

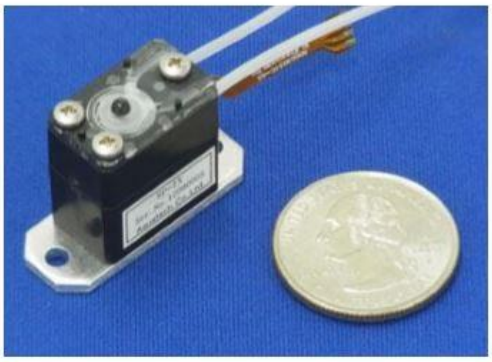
## APPENDIX 1

TAKASAGO ELECTRIC, INC.

2013.05

MICRO PERISTALTIC PUMP

**RP-TX Series**



Pulse Speed Display & Controller

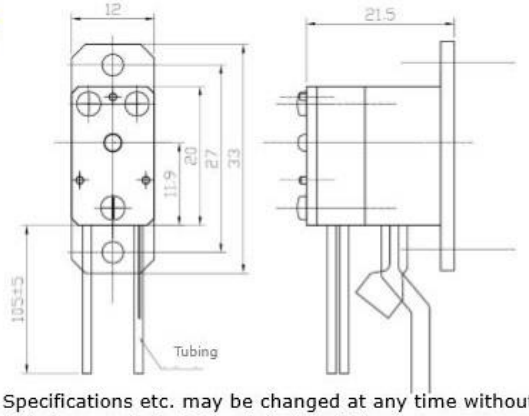
### Features

- The world's lowest level of flow for a peristaltic pump on the market: 0.1 ~ 40 µl/min
- A replaceable pump head, which includes tubing.
- Compact size: Dimensions of 33 × 12 × 21.5 mm
- An easy-to-use controller is available upon request. (Sold separately)

### Specifications

| | |
|---|---|
| Flow Rate | 0.1 ~ 40 µl/min ±15 %<br>(Water at 25 °C, Pulse speed: 3 ~ 1000 pps) |
| Tubing Material | Silicone or Olefine (I.D. 0.5 mm) |
| Pump Pressure | 30 kPa or more |
| Motor | Stepper motor |
| Rated Voltage | 3 VDC |

### Dimension

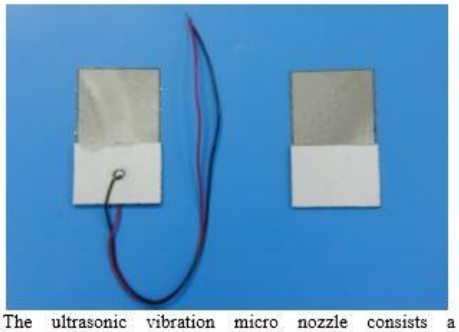



Note: Specifications etc. may be changed at any time without notice.
This is a product of Aquatech Co., Ltd.

TAKASAGO ELECTRIC, INC.
66 KAKITSUBATA, NARUMI-CHO, MIDORI-KU, NAGOYA, 458-8522 JAPAN
Tel +81-52-891-2301 Fax+81-52-891-7386
E-mail: info@takasago-elec.co.jp URL: http://www.takasago-fluidics.com/

**APPENDIX 2**

## Ultrasonic Vibration Micro Nozzle M2313500



The ultrasonic vibration micro nozzle consists a piezoelectric ceramic and a metal foil, on which over thousands micro nozzles formed. Using the same principle as inkjet printer, this transducer atomizes water or liquids through a matrix of micro holes of around 7-10 μm.
The micro nozzles ultrasonic atomizing transducer can use siphon to draw small amount liquids to the surface of metal foil and then to atomize, which is much efficiency than the conventional ultrasonic atomizer for which a liquid tank with high level liquid has to be always loaded on the surface of ultrasonic transducers.

### Features

- Fine and consistent misted particle size
- Adjustable misted particle size
- No loaded liquids require as comparing with conventional atomizers
- High atomizing efficiency
- Less power consumption
- High stability and durability

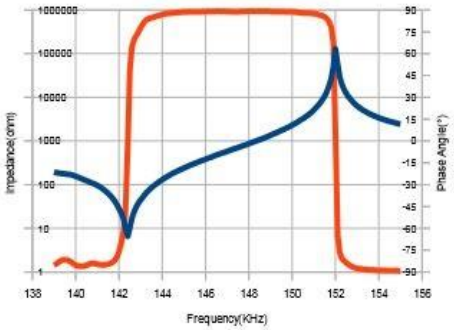
### Applications

- Humidification in refrigerated food displays and storage, living environments, and air conditioning plants.
- Inhalation and disinfecting equipment
- Humidification in industrial process control for lubrication, coating and etc.
- Liquids dispensing systems

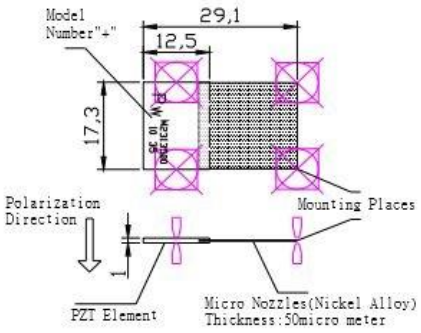
### Specification:

| | | | | |
|---|---|---|---|---|
| Resonant Frequency | | 143±5 | KHz | |
| Impedance | | 10 | ohm | typ |
| Capacitance | | 2300±20% | pF | @1KHz，20℃ |
| Dimensions | L | 29.1±0.2 | mm | |
| | W | 17.3±0.1 | mm | |
| | T | 1.0±0.1 | mm | PZT Element |
| Metal Material | | 50 | μm | Ni-Co Alloy |
| Nozzle size | | 7±3 | μm | |

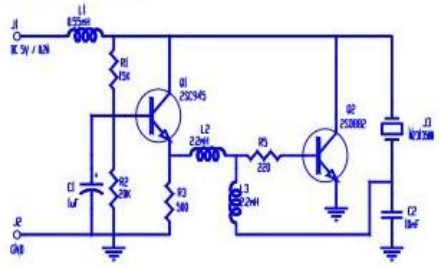
### Impedance/Phase Angle:




### Construction




### Driving Circuit



Remark: The negative side faces to the opening, the positive side faces to the liquid source, if driving circuit uses NPN transistor.


**S. Square Enterprise Company Limited**
**Pro-Wave Electronics Corporation**

Http://www.pro-wave.com.tw ; E-mail: sales@pro-wave.com.tw ; Tel: 886-2-22465101 ; Fax: 886-2-22465105

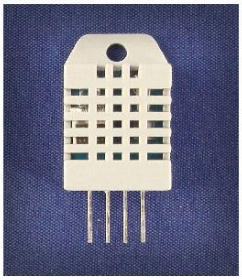
**APPENDIX 3**

# Aosong(Guangzhou) Electronics Co.,Ltd

Tell: +86-020-36380552, +86-020-36042809 Fax: +86-020-36380562
http://www.aosong.com
Email: thomasliu198518@yahoo.com.cn sales@aosong.com
Address: No.56, Renhe Road, Renhe Town, Baiyun District, Guangzhou, China

## Digital-output relative humidity & temperature sensor/module

## AM2303



Capacitive-type humidity and temperature module/sensor

### 1. Feature & Application:

* Full range temperature compensated * Relative humidity and temperature measurement
* Calibrated digital signal *Outstanding long-term stability *Extra components not needed
* Long transmission distance * Low power consumption *4 pins packaged and fully interchangeable

### 2. Description:

AM2303 output calibrated digital signal. It utilizes exclusive digital-signal-collecting-technique and humidity sensing technology, assuring its reliability and stability.Its sensing elements is connected with 8-bit single-chip computer.

Every sensor of this model is temperature compensated and calibrated in accurate calibration chamber and the calibration-coefficient is saved in type of programme in OTP memory, when the sensor is detecting, it will cite coefficient from memory.
Small size & low consumption & long transmission distance(20m) enable AM2303 to be suited in all kinds of harsh application occasions.

Single-row packaged with four pins, making the connection very convenient.

### 3. Technical Specification:

| | |
|---|---|
| Model | AM2303 |
| Power supply | 3.3-6V DC |
| Output signal | digital signal via single-bus |
| Sensing element | Polymer humidity capacitor & DS18B20 for detecting temperature |
| Measuring range | humidity 0-100%RH; temperature -40~125Celsius |

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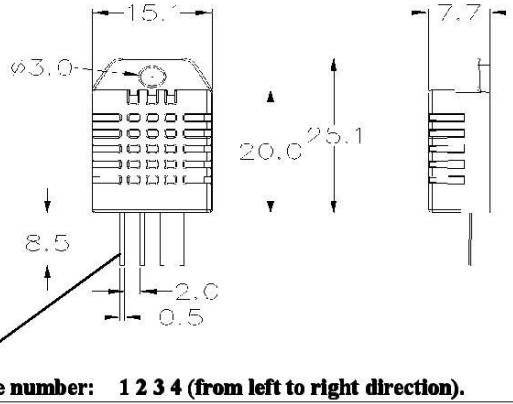
| | | |
|---|---|---|
| Accuracy | humidity +-2%RH(Max +-5%RH); | temperature +-0.2Celsius |
| Resolution or sensitivity | humidity 0.1%RH; | temperature 0.1Celsius |
| Repeatability | humidity +-1%RH; | temperature +-0.2Celsius |
| Humidity hysteresis | +-0.3%RH | |
| Long-term Stability | +-0.5%RH/year | |
| Sensing period | Average: 2s | |
| Interchangeability | fully interchangeable | |

## 4. Dimensions: (unit----mm)




**Pin sequence number: 1 2 3 4 (from left to right direction).**

| Pin | Function |
|---|---|
| 1 | VDD—-power supply |
| 2 | DATA--signal |
| 3 | NULL |
| 4 | GND |

## 5. Operating specifications:

**(1) Power and Pins**

Power's voltage should be 3.3-6V DC. When power is supplied to sensor, don't send any instruction to the sensor within one second to pass unstable status. One capacitor valued 100nF can be added between VDD and GND for wave filtering.

**(2) Communication and signal**

Single-bus data is used for communication between MCU and AM2303, it costs 5mS for single time communication.

Tell: +86-020-36380552, +86-020-36042809 Fax: +86-020-36380562
http://www.aosong.com
Email: thomasliu198518@yahoo.com.cn sales@aosong.com
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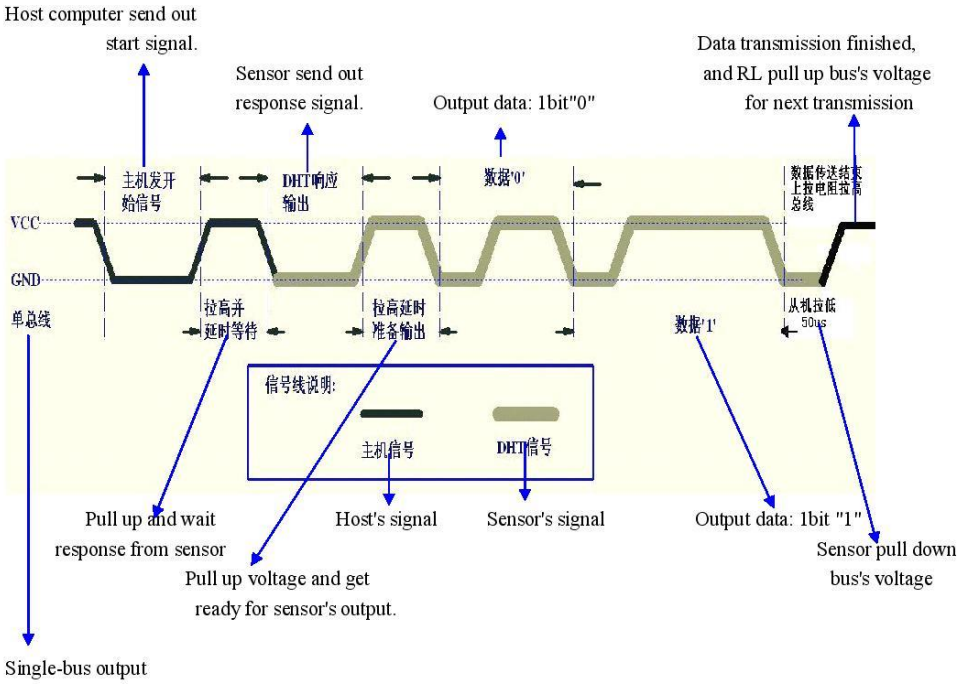
Data is comprised of integral and decimal part, the following is the formula for data.
AM2303 send out higher data bit firstly!
DATA=8 bit integral RH data+8 bit decimal RH data+8 bit integral T data+8 bit decimal T data+8 bit check-sum
If the data transmission is right, check-sum should be the last 8 bit of "8 bit integral RH data+8 bit decimal RH data+8 bit integral T data+8 bit decimal T data".

When MCU send start signal, AM2303 change from low-power-consumption-mode to running-mode. When MCU finishs sending the start signal, AM2303 will send response signal of 40-bit data that reflect the relative humidity and temperature information to MCU. Without start signal from MCU, AM2303 will not give response signal to MCU. One start signal for one time's response data that reflect the relative humidity and temperature information from AM2303. AM2303 will change to low-power-consumption-mode when data collecting finish if it don't receive start signal from MCU again.

1) Check bellow picture for overall communication process:



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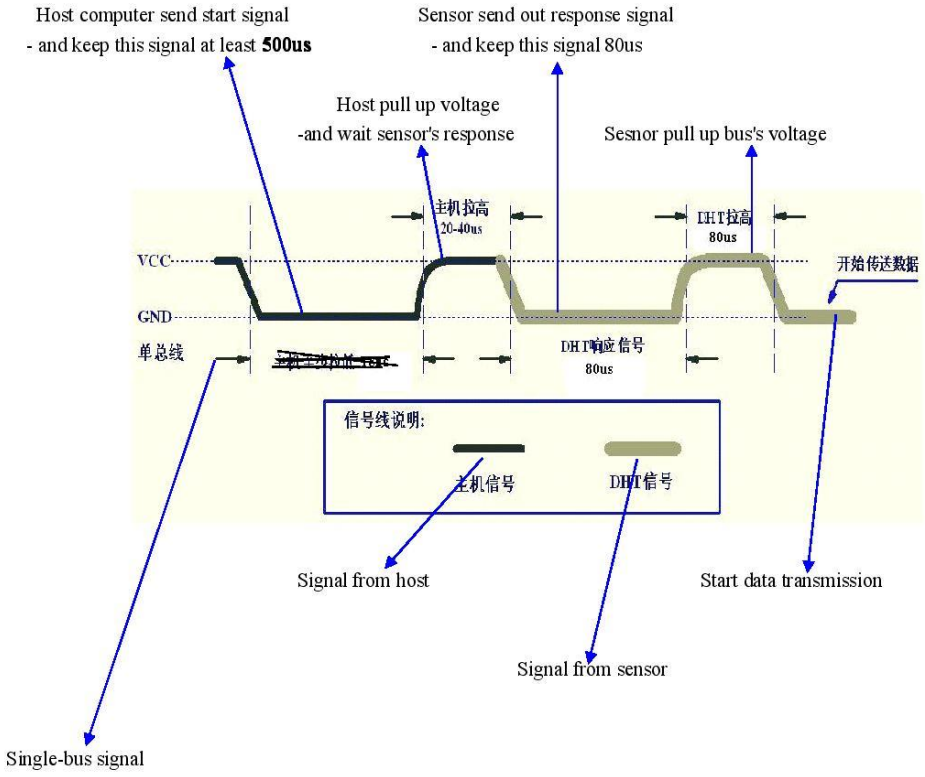
Address: No.56, Renhe Road, Renhe Town, Baiyun District, Guangzhou, China

2) Step 1: MCU send out start signal to AM2303

Data-bus's free status is high voltage level. When communication between MCU and AM2303 begin, program of MCU will transform data-bus's voltage level from high to low level and this process must beyond at least 18ms to ensure AM2303 could detect MCU's signal, then MCU will wait 20-40us for AM2303's response.

Check bellow picture for step 1:




Step 2: AM2303 send response signal to MCU

When AM2303 detect the start signal, AM2303 will send out low-voltage-level signal and this signal last 80us as response signal, then program of AM2303 transform data-bus's voltage level from low to high level and last 80us for AM2303's preparation to send data.

Check bellow picture for step 2:

Tell: +86-020-36380552, +86-020-36042809 Fax: +86-020-36380562
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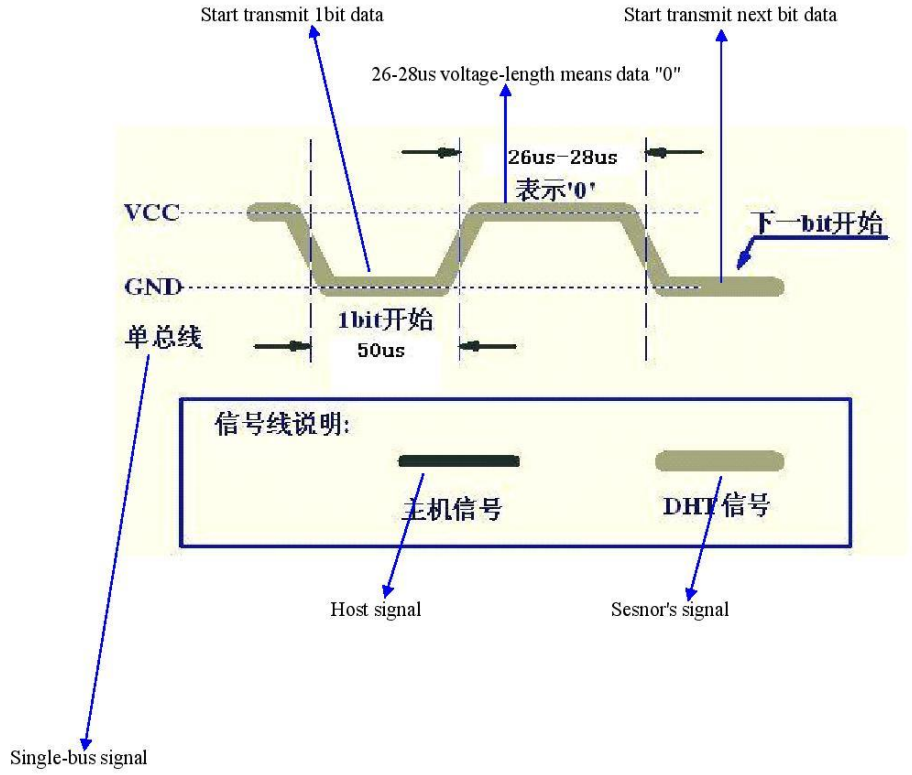
Email: thomasliu198518@yahoo.com.cn sales@aosong.com
Address: No.56, Renhe Road, Renhe Town, Baiyun District, Guangzhou, China

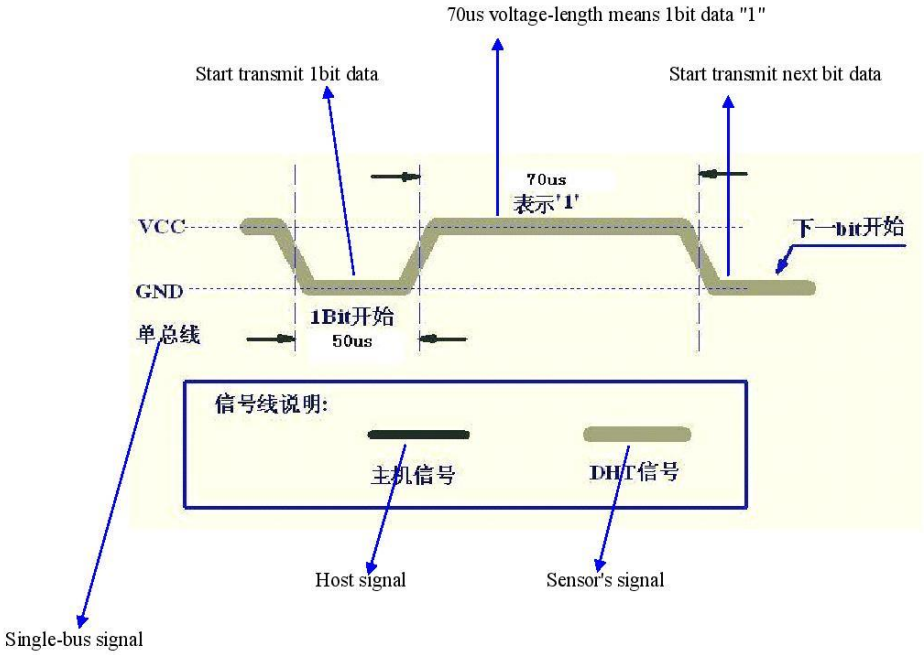



Step 3: AM2303 send data to MCU

When AM2303 is sending data to MCU, every bit's transmission begin with low-voltage-level that last 50us, the following high-voltage-level signal's length decide the bit is "1" or "0".

Check bellow picture for step 3:

Tell: +86-020-36380552, +86-020-36042809 Fax: +86-020-36380562
http://www.aosong.com
Email: thomasliu198518@yahoo.com.cn sales@aosong.com
Address: No.56, Renhe Road, Renhe Town, Baiyun District, Guangzhou, China




If signal from AM2303 is always high-voltage-level, it means AM2303 is not working properly, please check the electrical connection status.

## 6. Electrical Characteristics:

| Item | Condition | Min | Typical | Max | Unit |
|---|---|---|---|---|---|
| Power supply | DC | 3.3 | 5 | 5.5 | V |
| Current supply | Measuring | 1.3 | 1.5 | 2.1 | mA |
| | Average | 0.5 | 0.8 | 1.1 | mA |
| Collecting period | Second | 1.7 | | 2 | Second |

*Collecting period should be : >1.7 second.

## 7. Attentions of application:

(1) Operating and storage conditions

We don't recommend the applying RH-range beyond the range stated in this specification. The DHT11 sensor

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can recover after working in non-normal operating condition to calibrated status, but will accelerate sensors' aging.

(2) Attentions to chemical materials

Vapor from chemical materials may interfere AM2303's sensitive-elements and debase AM2303's sensitivity.

(3) Disposal when (1) & (2) happens

Step one: Keep the AM2303 sensor at condition of Temperature 50~60Celsius, humidity <10%RH for 2 hours;

Step two: After step one, keep the AM2303 sensor at condition of Temperature 20~30Celsius, humidity >70%RH for 5 hours.

(4) Attention to temperature's affection

Relative humidity strongly depend on temperature, that is why we use temperature compensation technology to ensure accurate measurement of RH. But it's still be much better to keep the sensor at same temperature when sensing.

AM2303 should be mounted at the place as far as possible from parts that may cause change to temperature.

(5) Attentions to light

Long time exposure to strong light and ultraviolet may debase AM2303's performance.

(6) Attentions to connection wires

The connection wires' quality will effect communication's quality and distance, high quality shielding-wire is recommended.

(7) Other attentions

* Welding temperature should be bellow 260Celsius.

* Avoid using the sensor under dew condition.

* Don't use this product in safety or emergency stop devices or any other occasion that failure of AM2303 may cause personal injury.

**APPENDIX 4**

Pololu Robotics & Electronics

DRV8834 Low-Voltage Stepper Motor Driver Carrier


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