FACE MASK

Preliminary Report

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EXECUTIVE SUMMARY

The purpose of the project is to design such a mask that will use for protecting from Covid-19 and also helps in breathing easily. It is a normal practice during the pandemic that people wear the masks but it makes them irritating after sometime and it becomes difficult to wear the mask for long time and hence the chance of spreading corona virus increases. Also, wearing regular masks covers the face and difficult to do the communication with others and usually it has seen that understating the words of presenter (wearing mask) is difficult and also sometimes visually seeing the face expression help in understand the others and it makes easy to do the communication but with the mask these things are not possible and non-verbal communication does not remain a way to do the communication while wearing the mask. In order to overcome all these issues, this project is designing a mask that helps communicating, and also makes easy to do the inhalation and exhalation process.

The mask has designed that is easy to wear for long time and it helps in breathing with the presence of respiratory system of inflowing oxygen through the fan and through the filter as well. The requirement of the project was to design a mask through which non-verbal communication is possible and it can use some electronics to help in communicating with others verbally through the use of mic and loud speaker. It can wear for long time without facing any trouble of inhaling and exhaling and it also protect from carrying any corona virus and along with that also keep safe from the dust. With all these features present in the device a design has made that covers the face properly and provides a filter that control the dirt particles but allow the regular air to goes in. And it also provides the pressure transducer to check the inside and outside pressure and when the pressure inside the mask drops, a fan will provide the respiratory flow of air into the mask and hence the inhaling and exhaling of oxygen will be easy and user will not feel any difficulty in wearing the mask. Along with that a small mic and speaker is present on the mask to do the communication easily.

The selected design has a filter at the front side and speaker is present at the at the bottom side of the mask. The selected pressure transducer for the design is MPXV7002DP while the controller selected is Arduino Nano, and SparkFun Mic and Speaker has selected to put in the mask, and HEPA Filter is using in the mask.

The project has implemented and the facemask is ready to use and it is a transparent mask which makes the communication easy and the presence of speaker and mic further enhance the communication and by using this facemask, the user can easily show his or her expression and the user can wear this facemask for longer period of time. While the presence of battery and the amplifier that attaches with the facemask but buckled at some other points can help in doing the communication easy and can wear for long period of time.

The risk and trad-off analysis has performed and from the analysis it is clear that the device has to use with great care otherwise chances of damage will increase and for the failures, some components can fail in the device but the chance of failing is quite low, while in case of any failure the trade-off is to wear the mask without suing the electronic system and remove the mask after sometime to get some fresh air, until the respective component will reinstall.

ACKNOWLEDGEMENT

The team would like to acknowledge out project client, instructors, sponsors and all those who helped the team in building the project. The team want to say thanks to the university for giving them a chance of working over such a brilliant idea

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1 BACKGROUND

1.1 Introduction

It has seen during the pandemic of corona virus, use of face mask has become necessity, important and must to wear so that it can save the person from getting indulge with the virus. The virus itself has a structure that insert through the mouth and infect the lungs, and this virus can cause the death as well. The best way to become safe from the virus is by using the mask, because it covers the mouth and do not let the virus enters into the mouth. But there are some difficulties in using the mask like breathing problem, inhaling and exhaling of oxygen into the lungs and even a person wearing mask is difficult to recognize.

Another problem using the face mask is that it is useful for short duration but for the long time it is not suitable as the virus molecules can sustain over the mask, so the risk of attacking the virus increase with the mask even. Another problem by wearing a mask is that non-verbal communication is difficult to understand because lips are cover, even more then half of the face is cover by the mask so expressions cannot see and non-verbal communication become difficult. Furthermore, a person wearing a mask need to speak loudly so that the listener can understand.

With all these difficulties in wearing the regular masks that include cloth masks, KN95 masks and other masks, there is a need of such a mask that will overcome all these difficulties and will not cover the face as well so that the person can recognize easily. This project is about designing such a mask that will not cover the face, and it will easy to wear for long time. The mask will help in breathing as well by using electronic sensors.

This project is of interest for the sponsors because of its need in the current pandemic and the idea is quite attractive that will not only help to fight this pandemic but it will be useful in the future as well. Another reason for the sponsor interest is that this mask will provide the relief and because of its useful features it causes the sponsors to take interest in it. The project will cause the benefit to the stakeholders in all the ways as the mask is beneficial to use for long time and easy to wear.

This project is important because it covers all the contemporary issues faces by wearing the masks and wearing the masks for long time is really important. Hence this face masks will make the life of stakeholder easy and will let them safe from the pandemic corona virus, hence this shows how important this project is.

1.2 Project Description

The project requires to design a face mask that will help the users to keep it waring for long time. It contains the following features:

A differential manometer will monitor the pressure inside the mask and infer the phase of respiration. The monitor detects a pressure below atmosphere (vacuum), a small fan puffs in filtered air to aid inhalation.

As pressure exceeds atmosphere (exhalation), a pilot-assisted check valve opens outlet ports that direct the flow down and desecrates it.

There should be a microphone in the mask that senses the wearer’s speech and plays it through speakers on the outside of the mask.

This should be powered with a rechargeable battery worn somewhere on the body that will provide hours of use between charges/battery swaps.

2 REQUIREMENTS

In this project it needs to design a face mask that will use the technology in such a way that it will help the user in breathing, communicating, and saving from the attack of corona virus. This section will present the customer requirements that has provided by the client and convert them into the engineering requirements. These requirements will use in the next sections as well to select the final design and identify if the objectives have met by the design or not.

2.1 Customer Requirements (CRs)

Customer requirements are the objectives and project descriptions provided by the client. The client provides the description in the form of paragraphs, while it will convert them into the table. The table contains the important points from the project description and this table has given the name customer requirements. The design has to fulfill the customer requirements in order to become successful design. The requirements table has given below:

Table 1: Customer Requirements

Customer Requirements
Allow unrestricted exhalation and inhalation
Allow unrestricted speech and non-verbal communication
Allow easy eating and drinking while wearing mask
Allow uninterrupted operability in an 8-hour working day
Speaker present to make the voice loud
Easy to wear
Not act as a carrier of virus
Reliable
Durable

These requirements have generated from the project description provided by the client.

2.2 Engineering Requirements

These are basically the technical requirements, and it contains numbers as well. In simple words engineering requirements are quantitative values while CR's are qualitative values. Engineering requirements contains the numerical values set as a target and these numerical values use in the future to test the design whether the design is meeting the requirements or not. These requirements must present in the design and each requirement can easily measure in the design to confirm to which extent the project design is fulfilling the need of client. These requirements have generated from the customer requirements and have shown below in the table.

Table 2: Engineering Requirements

Engineering Requirements	Operational Values
Length	< 8 inches

Battery Time	> 8 hours
Expiration Rate	6 liter/min
Tidal Volume	0.5 liter
Transparent Material	< 2
Weight	< 50 g
Battery Capacity	2500 mAh
Filter Size	< 300 m x 300 m

These requirements will use for designing the project and these will use to test the design as well in order to see which engineering requirements have met by design.

The length of the mask is important feature because it describes how much area it will cover on the face, therefore the size of 8 inch maximum will be enough to cover the face properly.

The battery time is the ON time of battery and it will provide the supply to the mask, so longer the duration is better and hence 8 hours at least should be the battery time of product.

Expiration rate is the rate at which the oxygen is entering into the mask, and in other words it is also known as flow rate of oxygen and it should be 6 liter/min maximum.

Tidal volume is the volume of air that can cross the mask and it should be around 0.5 liters.

The transparency of material describe through the index level and air index is 1, while glass index is 1.5, so the index of the material should be less than 2 so that face can clearly visualize.

The mask should be light in weight and hence the maximum weight it can gain is 50 grams.

Battery capacity is the capacity of energy it can store and hence it can store maximum of 2500 mAh.

Size of filter is from where the oxygen will enter and leave from the mask and the maximum size of that filter should be 300 m x 300 m.

2.3 Functional Decomposition

Functional decomposition is basically describing the functioning of the project, what is coming as input into the system, while what is getting from the system as output. While the functioning inside the system also describes in functional decomposition. There are two function models, black box model and functional model uses to describe the complete functionality of a function.

2.3.1 Black Box Model

The black box model shows the inputs and outputs of a system without defining what is happening inside the system. It only shows the number of inputs, types of inputs and number of outputs and what are the outputs. Here is the black box model for the system

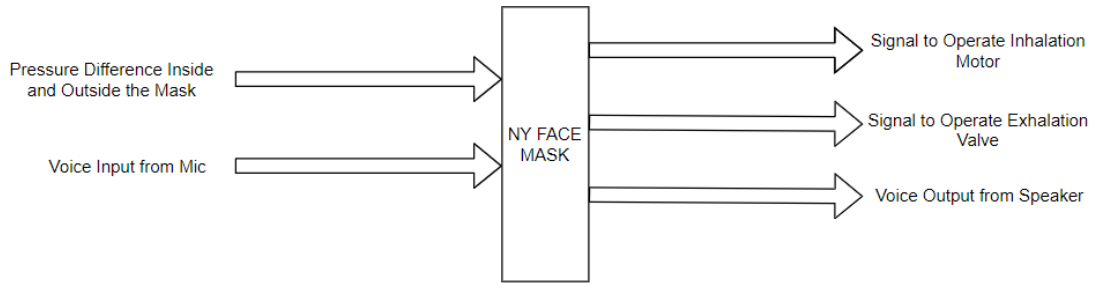

Figure 1: Black Box Model

In the above model there are two inputs, one is taking the pressure difference from the inside and outside of the mask, and second input is voice input from the microphone. And there are three outputs inhalation system, exhalation system and voice coming from the speaker.

2.3.2 Functional Model

The functional model describes the functionality of a device from the internal point of view, as it shows how the signals at the inputs converts to the output and through which path it generates the output. All the functioning inside the system describe in the functional model. Here is the functional model

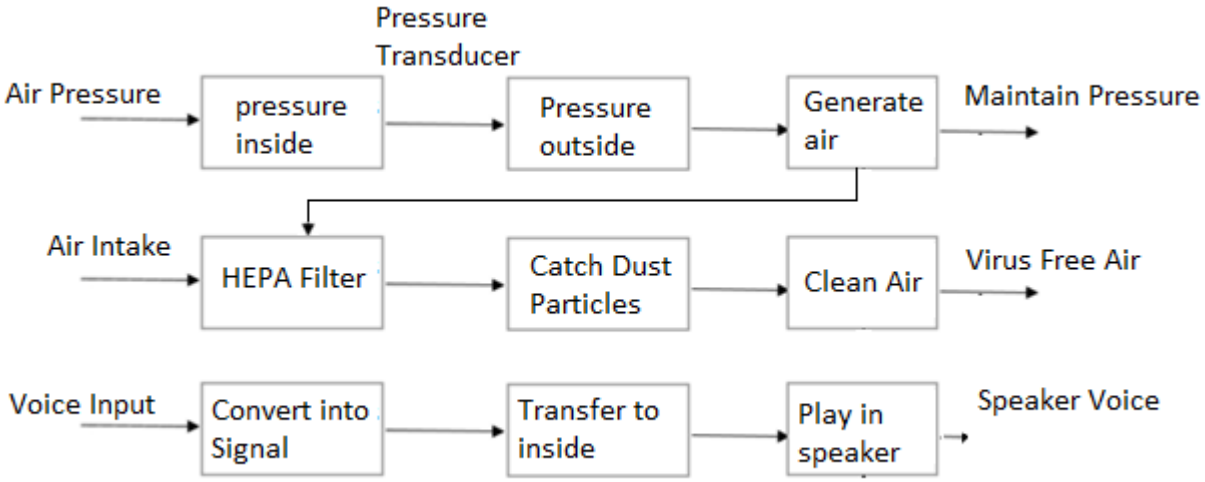

Figure 2: Functional Model

The functional model describes the internal function of the project. This function model has changed from the previous model and few things have added in it. Like in old functional model there was no filter present, so in this functional decomposition filter has added in it. Furthermore, pressure transducer was not mentioned in the old functional model so pressure transducer has introduced in this functional model as well to clearly define the working of design.

2.4 House of Quality (HoQ)

This is a chart to uses to make the relation between customer requirements and engineering requirements, and from the relation a priority order of engineering requirements can generate.

The priority order will tell which engineering is most important and which engineering requirement is least important. For each customer requirement, it analyze against each engineering requirement and assign a number that describe how strong these two relates to each other. The chart has given below

Table 3: House of Quality

Customer Requirement	Weight	Engineering Requirement	Length	Battery Time	Expiration Rate	Tidal Volume	Transparent Material	Weight	Battery Capacity	Filter Size
Unrestricted exhalation and inhalation	9		3		9	3				3
Unrestricted non-verbal communication	9		1		1	3	3			1
Easy eating and drinking	9		1		1		1	1		
Work for long time	3			9				1	9	
Speaker present to make the voice loud	3			1				3	3	
Easy to wear	3		3		1	1	1	3		
Not act as a carrier of virus	3									
Reliable	1						1	1	1	
Durable	1						1	1	1	
Absolute Technical Importance (ATI)			54	30	102	57	41	32	38	36
Relative Technical Importance (RTI)			14%	8%	26%	15%	11%	8%	10%	9%
Target ER values			8 in	8 hours	6 l/m	0.5 l	2	50 g	2500 m	300x300m
Tolerances of Ers			2 in	1 hour	2 l/m	0.1 l	1	10 g	200 ma	5x5 m^2
Testing Procedure (TP#)			1	2	3	4	5	6	7	8

It is clear from the house of quality that the most important engineering requirement is expiration rate, and the least important requirement is weight.

2.5 Standards, Codes, and Regulations

Following standard and codes applies to this project:

- American Society of Testing and Materials (ASTM)
- Institute of Electrical and Electronics Engineers (IEEE)
- Geometric Dimensioning and Tolerancing (GD&T)

These standards have described below in the table

Table 4: Standards applied to the project

Standard Number or Code	**Title of Standard**	**How it applies to Project**

ASTM	American Society of Testing and Materials	This applies to the project for using the materials, the material that will use to build the device must pass the ASTM standards.
IEEE	Institute of Electrical and Electronics Engineers	This applies to the project as project is using electronic devices and to use such devices, they have to be in use by the IEEE standards.
GD&T	Geometric Dimensioning and Tolerancing	This applies to the designing of mask; the dimensions have to follow the GD&T rules.

3 DESIGN SPACE RESEARCH

In chapter 3, it talks about the research which is important for any design project. The design project needs a creative design which can be done by doing a good research because it helps in finding the old works done on the same concepts and from the existing work new ideas can generate and also get the help of how to implement any design. The understanding of main functions, and sub-functions can also be done through the research therefore it is important to perform a proper research about the design project to expand the thinking about the project.

3.1 Literature Review

The strong state computerized transducer speaks to another norm in exactness pressure transduction for the up-and-coming age of airborne sensors. The pressure transducer produces beat train yields as a proportion of pressure by creating strains in a silicon stomach which fuses piezoresistive detecting components [3]. These components are dispersed opposition capacitance (RC) networks which are diffused into a stomach surface as the control components of stage move oscillators. By this methodology, an advanced (recurrence) signal produced at the source can be communicated without commotion and separation impediments and the requirement for accuracy simple to computerized change is killed. The gadget displays points of interest in the territories of unwavering quality, precision, size and cost over present-day simple gadgets. The strong state advanced pressure transducer is being created to meet the necessities of supersonic and subsonic air information applications when combined with an elite air information PC. This application requires low hysteresis with repeatability and soundness which are the fundamental highlights of the strong state pressure transducer. Other potential applications are FM information obtaining frameworks and modern robots.

Another kind of an air purifier has been created for a synchronous control of airborne, microbial, and scent in living conditions utilizing ozone, crown pre-charger, an electric miniplates channel, and an ozone-decaying catalyzer just as a semiconductor ozone sensor for wellbeing control. Ozone is created in the crown pre-charger by improving negative crown with the utilization of a higher-than-conventional voltage [4]. This gadget, which is named AIP, shows 85% one-through number assortment effectiveness for airborne particles in the size scope of 0.1-1.0 mm. AIP shows an extremely good freshening up execution for man-began and living climate started smells, for example, alkali, hydrogen sulfide, methyl-mercaptan, and so on The AIP likewise successfully slaughters, through long presentation to low-focus ozone, most microorganisms, organisms, infections, and different microbials and little creepy crawlies gathered in its channel.

This paper presents the ease power converter learning unit for power gadgets lab in the undergrad electrical designing course. This paper likewise inspects the learning result of an Arduino Nano and MOSFET based converter learning pack. With assistance of this converter pack, the understudy can become familiar with the working and control of a wide range of fundamental force converter circuits which is available in their electrical designing undergrad educational program. This is an attachment and play sort of learning pack with least association changes needed to change over from one kind of intensity converter to different sorts of intensity converter circuit. This learning pack encourages to learn and control all sort of essential force converter circuits like the chopper, inverter, AC voltage regulator, and rectifier. It underpins the

single stage just as the three-stage power transformation and control. The absolute expense of the fundamental converter unit is under Rs.1400 i.e., which is under $20 [5]. The successful helpfulness and simplicity being used of the pack are assessed by the criticism from the third-year understudies of electrical designing course. The aggregate criticism result shows the ease converter pack is a lot of supportive to comprehend the fundamental ideas of the force converter circuit.

The correlative presentation and investigation of a sort of modern field pressure estimation sensor is completed in this paper by us. The rule of work and force flexibly circuit of pressure sensor is concentrated in detail [6]. The steady current source power flexibly mode is received in this paper, which is awesome for sureness of estimation. So as to go a further advance to investigate affectability circumstance affectability execution, limited component examination research strategy is taken for the pressure sensor chip for a few times. By methods for limited component investigation, we realize that the pressure sensor has great affectability and level of linearity. This paper gives a few significant logical references to exploring and planning the pressure sensor.

This paper presents the plan and examination of high touchy stomach for electret receiver applications. All in all, the affectability of electret receiver relies upon the electrical affectability and the mechanical affectability of the stomach. The high mechanical affectability can be controlled by the mechanical properties of the stomach. So as to get high touchy receivers, the properties of low tractable pressure and bigger territory of the stomachs were manufactured. In this examination, the spacer and the thickness of the backplate of electret mouthpiece are 16 mum and 120 mums, individually [7]. The stomach made of polyimide and Si 3 N 4 materials with different thickness and region were assessed. It was discovered that the stomach made of polyimide gives the better affectability as thought about that made of Si 3 N 4 materials. Then again, the bigger territory of stomach brings about the higher affectability of the receiver. The comparing affectability is 9 mV/Pa in the recurrence scope of 50 Hz to 12 kHz under the electret material with - 120 V.

3.2 Benchmarking

Some of the existing designs will discuss in this section that have found after the research. These existing designs consist of main function and also existing designs consists of sub-functions as well.

3.2.1 System Level Benchmarking

The system level existing designs are presenting in this section.

3.2.1.1 Existing Design # 1: 1982 Mask

This mask is a unique mask in the shape, while it contains a filter but the clothing in the mask is irresistible and it will be difficult to wear this mask for long time. Here is the existing design showing below

Figure 3: 1982 Mask [4]

3.2.1.2 Existing Design # 2: Rsenr Mask

This is another type of mask already existed, and in this mask there are dust mask respiratory filters which can replace as well and it covers the face properly and tightly held with the nose so that no dust can cross the mask, but the problem is still the same, respiratory system does not work good with this mask when wearing for long time and it has shown below [5].

Figure 4: Rsenr Mask [5]

3.2.3 Existing Design # 3: DM Zing Mask

In this existing design, the mask covers the face almost more than 50%, and from the mask respiratory system works well for short period of time, while for long period of time it takes difficult to breath well and it covers the nose tightly so it causes trouble to the nose as well. The design has shown below [6].

Figure 5: DM Zing Mask [6]

3.2.4 Existing Design # 4: Broad Mask

This is a type of mask which covers the face broadly and provide a gap between mask and lips, while it is useful for longer period as well but the respiratory system does not work good in this mask even for short period of time because of its dust filter and it has shown below [7].

Figure 6: Broad Mask [7]

3.2.2 Subsystem Level Benchmarking

The subsystem level of the project contains different components like pressure transducer, speaker and microphone, air discharge valve, air filter, battery etc. From these subsystems a pressure transducer is describing in this section.

3.2.2.1 Subsystem #1: Pressure Transducer

It is a device that uses to determine the pressure at one point and it can use to determine the difference in the pressure from one point to another point like it can use to find the pressure difference inside the mask and outside the mask.

3.2.2.1.1 Existing Design # 1: BPE282

This is a pressure transducer that has accuracy like 80%, while the cost of the transducer is high and it consume lot of power and produce noise as well. And it has shown below

Figure 7: BPE282 [8]

3.2.2.1.2 Existing Design # 2: MPXV7002DP

This is another existing design in which the transducer can give high accuracy, and it cost les as well. While the power consumption is low as well in this transducer. And it has shown below.

Figure 8: MPXV7002DP

3.2.2.1.3. Existing Design # 3: ESP8266

Another existing design for the pressure transducer is presenting here, in which the cost is not effective but the accuracy is the main issue which is quite low.

Figure 9: ESP8266

3.2.2.2 Subsystem # 2: Controller

Controller is using to control all the components in the device, each instruction transfers from the controller to each component, and there are different types of controllers available stating in the following section.

3.2.2.2.1 Existing Design # 1: Arduino Nano

The Arduino nano gives all the features in the single chip and it provides an easy way to code the controller. Arduino provides an easy access to do the communication as well. The cost of Arduino is low [11].

Figure 10: Arduino Controller

3.2.2.2.2 Existing Design # 2: Raspberry Pi Controller

Raspberry Pi controller is another controller uses to communicate with the components. It also provides the LAN access as well but the cost of raspberry is high.

Figure 11: Raspberry Pi

3.2.2.2.3 Existing Design # 3: BeagleBone Controller

This is a high-speed controller with the ARM processor and it contains high memory as well but the cost of the product is high.

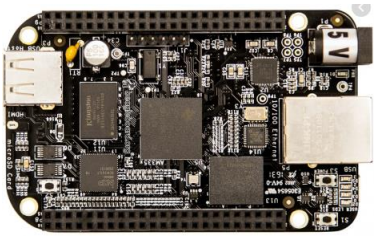

Figure 12: Beaglebone

3.2.2.3 Subsystem # 3: Microphone

This is another subsystem uses to communicate with others. The microphone will help in amplifying the voice of the user and it can make easy to understand by the others.

3.2.2.3.1 Existing Design # 1: SparkFun Electric Microphone

This is a microphone that uses to transfer the voice clearly from one end to another end. The cost of this product is low as compare to the other microphones available in the market.

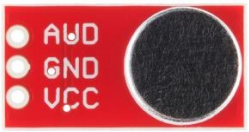

Figure 13: SparkFun Electric Microphone

3.2.2.3.2 Existing Design # 2: Adafruit Electret Microphone

This is an existing design and the microphone contains the adjustable gain with the amplifier settings while the cost of this product is higher than the SparkFun microphone.

Figure 14: Adafruit Microphone

3.2.2.3.3 Existing Design # 3: Comidox

This is a high sensitivity microphone while noise ratio is high in this module and it has shown below in the following figure.

Figure 15: Comidox

4 CONCEPT GENERATION

The concept generation is the most important part in any design project. In this section all the different ideas have generated and then compared with each other to select the final design.

4.1 Full System Concepts

4.1.1 Full System Design # 1: Cloth Mask

This is a design in which the cloth is using as a material to make the mask, while it contains the filter as well for the respiratory system. This cloth mask will cover tightly with face and keep the dust particles away. The mask can use to protect any sort of Corona effect as well.

Advantages:

1. Comfortable
2. Low Cost

Disadvantages:

- Integration of components is difficult

Figure 16: Cloth Mask

4.1.2 Full System Design # 2: Plastic Mask

This design of mask consists of plastic, while it contains the polynomial surface as well to provide an easy to use mask. The mask will cover the whole face while it will provide the filter for the inhale and exhale system.

Advantages:

- Low Price
- Systems can integrate easily
- Easy to use
- Comfortable
- Easy to Manufacture

Disadvantages:

- Can break easily if pressed harsh.

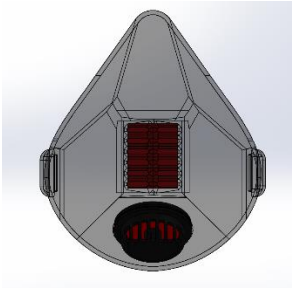

Figure 17: Plastic Mask

4.1.3 Full System Design # 3: Curved Plastic Mask

Another design has created in which the mask has developed in the curved form and with the material.

Advantages:

1. Comfortable

Disadvantages

1. High cost
2. Difficult to manufacture
3. Difficult to integrate the components

Figure 18: Curved Plastic mask

4.2 Subsystem Concepts

Different sub-systems design has generated in this section.

4.2.1 Subsystem # 1: Pressure Transducer

4.2.1.1 Design # 1: BPE282

This is a pressure transducer that has accuracy like 80%, while the cost of the transducer is high and it consume lot of power and produce noise as well. And it has shown below

Figure 19: BPE282

Advantages:

- Low Cost
- Integrate with Arduino easily

Disadvantages:

- Low Accuracy

4.2.1.2 Design # 2: MPXV7002DP

This is another existing design in which the transducer can give high accuracy, and it cost les as well. While the power consumption is low as well in this transducer. And it has shown below.

Figure 20: MPXV7002DP

Advantages:

- Integrate with Arduino easily
- High Accuracy
- Low power consumption

Disadvantages:

- Little high price

4.2.1.3. Design # 3: ESP8266

Another existing design for the pressure transducer is presenting here, in which the cost is not effective but the accuracy is the main issue which is quite low.

Figure 21: ESP8266

Advantages:

- Integrate with Arduino easily

Disadvantages:

- Low Accuracy
- High Cost
- High power consumption

4.2.2 Subsystem # 2: Controller

4.2.2.1 Design # 1: Arduino Nano

The Arduino nano gives all the features in the single chip and it provides an easy way to code the controller. Arduino provides an easy access to do the communication as well. The cost of Arduino is low.

Figure 22: Arduino Controller

Advantages:

- All things are accessible in single unit

Disadvantages:

- Low strength Wi-Fi

4.2.2.1 Existing Design # 2: Raspberry Pi Controller

Raspberry Pi controller is another controller uses to communicate with the components. It also provides the LAN access as well but the cost of raspberry is high.

Figure 23: Raspberry Pi

Advantages:

- Controller is faster in speed

Disadvantages:

- Less memory available on the controller

4.2.2.3 Existing Design # 3: BeagleBone Controller

This is a high-speed controller with the ARM processor and it contains high memory as well but the cost of the product is high [13].

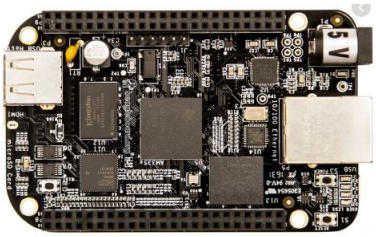

Figure 25: Beaglebone

Advantages:

- High speed

Disadvantages:

- Costly
- Low memory
- Less efficient

4.2.3 Subsystem # 3: Microphone

4.2.3.1 Design # 1: SparkFun Electric Microphone

This is a microphone that uses to transfer the voice clearly from one end to another end. The cost of this product is low as compare to the other microphones available in the market.

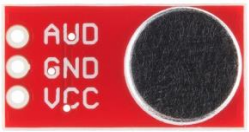

Figure 26: SparkFun Electric Microphone

Advantages:

- Fast
- Efficient
- Highly sensitive

Disadvantages

- Costly

4.2.3.2 Design # 2: Adafruit Electret Microphone

This is an existing design and the microphone contains the adjustable gain with the amplifier settings while the cost of this product is higher than the SparkFun microphone.

Figure 27: Adafruit Microphone

Advantages:

- Highly sensitive

Disadvantages

- Costly
- High noise

4.2.3.3 Design # 3: Comidox

This is a high sensitivity microphone while noise ratio is high in this module and it has shown below in the following figure.

Figure 28: Comidox

Advantages:

- Sensitive

Disadvantages

- Costly
- High noise

5 DESIGN SELECTED

For the chapter 5, it talks about generation of concept which are important to do for any designing project. And for the selection of final design there are different methods that need to use, which includes Decision matrix, Pugh chart, Pairwise comparison chart etc. These of the methods can help in selecting the final design on the criteria of engineering and customer requirements.

5.1 Technical Selection Criteria

For selecting the final design, the criterion is simple, that evaluate each design according to the engineering requirements and select the final design that fulfills the requirement maximum. It takes the grade to each design against each requirement and then sum all the values, higher the value will be the final design. This has done in both full systems, and also in subsystems.

5.2 Rational for Design Selection

The final design has selected through the following table

Table 4: Evaluation Chart

Criterion	**Possible Selection**	**Cloth Mask**	**Plastic Mask**	**Curved Plastic Mask**
Comfort		10	8	8
Aesthetics				
Manufacturability		7	10	5
Cost		9	10	6
Component Integration		4	10	6
Total		**36**	**47**	**35**

Hence the best design is Plastic Mask because it has the highest numbers and looking at the advantages, it is the one which contains the maximum advantages, and fulfilling the requirements of the project properly. While the other two designs have rejected and will not use. Here are the salient features of this design.

- HEPA Air filter at Both Inhalation and Exhalation Ports
- The outer frame of the mask will be 3D printed – Plastic Sheets will be pasted on polynomial shaped edges
- Suction Fan and Ventilation System will be fitted on the front Rectangular Inhalation Port
- Air discharge valve will be fitted onto Discharge Port
- Electronics are supposed to be fitted on the mask – The final design iteration is under progress which will provide provisions to fit electronics and battery

With all these features, the design is best to use among the other two designs. Also it is fulfilling the customer requirements as well:

- ✓ Allow unrestricted exhalation and inhalation
- ✓ Allow unrestricted **speech** and **non-verbal communication**
- ✓ Allow **easy eating and drinking** while wearing mask: We are working on design iterations to make it possible
- ✓ Allow **uninterrupted operability** in a **8 hour** working day
- ✓ "Surviving Facemask Experience with a Laugh" – Incorporate fun features like voice altering: This feature will be incorporated once the functional design is created

And this design is fulfilling the engineering requirements as well:

- ✓ Ventilation System - Tidal Volume of 0.5 L with Expiration Rate of 6 L/min
- ✓ Transparent Plastic material for manufacturing with wearable rubber at corner
- ✓ Arduino Nano based System electronic system
- ✓ Light-weight linkage mechanism: This mechanism is being designed for the facemask to provide provision for eating and drinking
- ✓ 2500 mAh battery supply

With all these requirements fulfilled by this design it has selected as a final design. Now coming to the sub-system selections. The table has shown below

Table 5: Pressure Transducer Selection

Criterion	**Possible Selection**	**BPE 282**	**MPXV7002DP**	**ESP8266**
Accuracy		8	10	5
Cost		10	9	7
Integrability with Nano		10	10	10
Power Usage		8	10	8
Signal Noise		8	10	6
Total		**44**	**49**	**36**

Hence the best transducer to use is the MPX transducer, while the BPE282 transducer can set up as a backup plan in case the MPX transducer does not work properly.

For the selection of controller following table has used.

Table 6: Controller Selection

Criterion	**Possible Selection**	**Arduino Nano**	**Raspberry Pi**	**BeagleBone**
Accuracy		10	10	5
Cost		10	9	7

Integrability		10	8	10
Power Usage		10	8	8
Signal Noise		10	10	6
Total		**50**	**45**	**36**

Hence the best solution here is Arduino Nano to use in the device and the other two controllers are not setting up for any back up plan because of the reason that Arduino has the capability to easily handle this system. And looking at the advantages of Arduino, it is more then other two controllers, that's why it has selected.

For the selection of microphone following table has used:

Table 7: Microphone Selection

Criterion	**Possible Selection**	**SparkFun**	**Adafruit**	**Comdix**
Accuracy		10	7	5
Cost		8	7	7
Integrability		10	8	5
Power Usage		10	8	8
Signal Noise		10	8	6
Total		**48**	**38**	**31**

Hence the selected design is SparkFun microphone because of its higher advantages stated earlier. While the other two designs are rejected. Some other parts have selected using the following criteria.

HEPA Air Filter

Here are some details about HEPA air filter

- Cannon HEPA Air Filter
- Product Cost: $12.6
- Filter Size: 296 by 296 mm
- The filter will be cut into small pieces for inhalation and exhalation ports of the mask
- Particulate Size: PM 2.5 hence suitable for COVID-19 Airborne Particle

5.2.1 Final Design

The final design CAD model has created and it has shown below

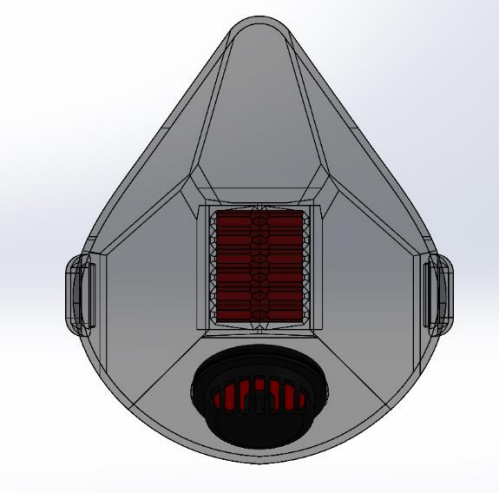

Figure 29: Final CAD Model

Another view of CAD model has shown below

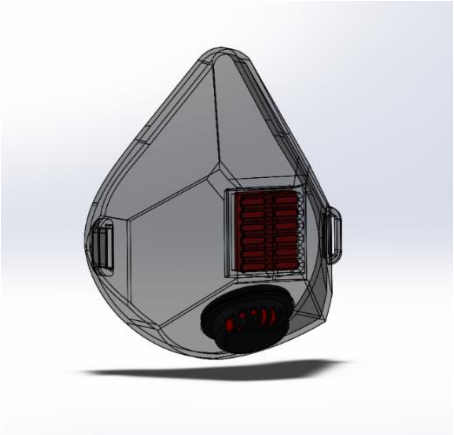

Figure 30: Final CAD Model side view

6 IMPLEMENTATIONS

The implementation starts with some initial work that has done in Capstone I and then in Capstone II the implementation has done completely. First of all, the components have ordered online. It was a bit difficult to find some materials but we have found the related materials and components and placed the ordered. Most of the components have arrived on time as well but some components faced more delay in delivering than the expected time.

Fabric- We needed a material that is soft on the face and also it may possibly be the outer layer. The inner layers will be different types of foam that are glued together and connected to the clear plastic center portion flanges.

Foam- The foam required was neoprene foam which is very rubber-like.

Filter material- MERV 16 Filter Material Roll - Made in USA - Breathable Non-woven

Polyester Polycarbonate - 95 Percent Efficiency - DIY Cut to Fit Face Mask Filter Inserts.

Plastic- For face shield plastic material has selected to mold it.

Sculpting clay/plaster- The sculpting clay has ordered to mold it into facemask look.

Electric bands/snaps- Most masks have very thin elastic bands we're going to use a wider design that should be more comfortable. They will be made with snaps so they will be removable and even replaceable. That is the weak point of many masks, the elastic band wears out. We will have various sizes in order to perfectly fit every face.

Glue- Black silicone has ordered to attached the sheets of foam together as well as to the plastic centerpiece. It is non-toxic and will bomb the materials very well diamond is not affected by water or moisture.

Mic/speaker- We have located a device that a person giving a speech might use in front of a crowd. It's a headset that has a wired small speaker. We may use a different microphone that does not have the speaker headset portion or we will just remove the microphone from this existing unit. We want the smallest possible mic that still gives good quality results. We understand there will be an echo within the mask and it will be important to use the open cell foam to surround the microphone to reduce any feedback.

Fan- It looks like the smallest possible fans are 30mm x 30mm x 7mm. The main concerns will be the power of the fan along with the noise or decibel level of the fan.

Fan and filter housing- We needed to create a housing or way to connect the fan to the mask as well as the exhaust filter on the opposite side. These pieces will likely need to be 3D printed.

Wire connectors- We needed the wires and connectors to make the connections streamline and as neat as possible.

Batteries- We used lithium-ion polymer cells that are rectangular in shape or 18650 lithium-ion cells that are cylindrical with a metal housing. The lithium-ion battery also required a battery management system (BMS) to safely monitor charging and discharging.

Mannequin head- It can be much easier to fit fabrics to an actual face and understand if the design is a good fit or not prior to actually making any cuts or wasting material.

First of all, a transparent face shield has ordered so that different components can test over it and some tests have done as well like placing a fan in it to see the adjustment of fans. The microphone and face have added in this facemask and it has observed that there is slight noise in low volume but at high volume the anticipation is high that need to tackle.

Figure 31: Face Shield

Epoxy resin has purchased for making the facemask and it will be used if the plaster does not work well for the mold. The problem with the plaster is that it might not be strong enough, while this epoxy resin is little bit more difficult and messier to work with but it's much stronger. The epoxy resin has shown below

Figure 32: Epoxy Resin

For the innermost and outermost layers of the mask, soft cotton will use, the team has ordered three different types of soft cotton and will test each of them to see which soft cotton type is best to use and it has shown below

Figure 33: Soft Cotton

A face field has ordered that will be using for the center plastic insert. As the face mask will need to be sturdy enough so this face field will help in it. The purchasing of face filed has done quickly then the expected time as it has reached before the expecting time.

Figure 44: Face Field

Following image is showing different kind of foams that the team has ordered and the purpose of ordering these foams is to check practically which suits best for the facemask. And the reason to use foam is to keep it soft over the hard edges where it will intact with nose and ears.

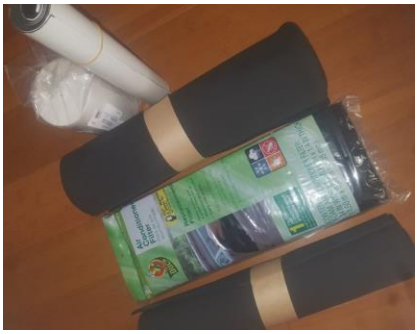

Figure 45: Foams

Two types of glues have ordered and both of them have arrived as well, both are non-toxic, one is a silicone sealant and it is of food graded as well while the other is a regular using glue for connecting the foams.

Figure 46: Glues

Different kind of fans have ordered, as the fan will use to provide high speed air for inhaling process. The reason for ordering different kind of fans is to find the best fan that will have no noise because the air noise can disturb the mic as well so the team need such a fan that produces almost no noise. All of these fans have tested to determine the noise and also effectiveness in moving air. Results have shown that all fans have same level of noise except one fan that has no noise but it also has a constraint that it provides zero moving air. These fans are of 5 volts or 12 volts and all of them have shown below. In the following fans, the fan present on the rightest side blows much stronger and it is a thinner fan so the most probable chance is to use that fan.

Figure 47: Fans

A voice amplifier with the mic and speaker has ordered as well, the amplifier will set with the waistband or belt while it will provide the mic and speaker to enhance the communication.

Figure 48: Amplifier

In the following image plaster of Paris is showing that will use to make molds for the facemask and it has shown below

Figure 49: Plaster of Paris

Elastic bands are showing below, and these will use around the facemask to cover the face and help in sticking the mask with the face. These are long elastic bands, so these are adjustable and comfortable and because of the size they are less likely to deteriorate and stop working like the thing elastic bands do.

Figure 50: Elastic Bands

The metal snaps to use with the elastic bands have shown below, these metals snaps will use to stich the bands with the facemask. These are different in sizes and can use for different purposes in the facemask to hold components as per need.

Figure 51: Metal Snaps

The following mannequin head has ordered has well to make the facemask by using this face. The team is going to manufacture the facemask through the plaster of Paris and the molding will be done on this face. In order to get a better shape of facemask, the team may do some changes in this face.

Figure 53: Mannequin Head

Another type of clear mask has purchased as well to get the best feature shaped mask so that the facemask shape can get become better.

Figure 54: Facemask

Clay has also purchased to make the basic shape of facemask on the model. Then plaster will be poured over the clay there will be a wall built around the face to trapped in plaster and keep it in place.

Figure 55: Clay

The filter that the team is using is n95 material and it is hospital grade material. It is three layers and Merv 16 efficiency rated, level 4 microbial resistance, breathable, non-woven polyester polycarbonate. This has shown below in the following image

Figure 56: Filter

The inside of amplifier has shown below as it can clearly see that there is a mic present in it and there is a battery pack present in it along with the speaker. This amplifier can work for 8 to 10 hours with the voice amplifier functions. It has 18650 cells that has a capacity of 1800 milliamp

hours. The battery capacity can enhance to reach to 3500 milliamp hours because the cell size will remain same and hence the size of battery remains same with the increased capacity and it can decide after testing if the battery capacity need to increase or not.

Figure 57: Amplifier from Inside

Figure 58: Battery

The microphone close up has shown below and in this close up it can clearly see that the size of microphone is quite big and the team wasn't expecting the mic of this size, therefore the team will change this microphone with another microphone of smaller size because it needs to fit in the mask and this size microphone is difficult to fit in the mask. The smaller size microphone needs to order again.

Figure 59: Microphone close-up

The following picture is showing the testing for snaps used to stich different foam and fabric. This is just a demonstration that it will use in the project in same way to install foam and fabric as needed to do.

Figure 60: Snap Stitching

The glue tests have done as shown below. These are tests using the flues to attached different pieces of foam together. The glue's performed very well on the test. And They didn't even have near enough time to fully cure but still it worked well in it. In the well bonded areas, the foam was ripping itself apart rather than the flue coming apart. That is exactly what the team was looking for and hence the glues we have purchased were perfectly good to go in the project.

Figure 61: Glue Tests

Facemask Making

The making of facemask is the most difficult and tedious task in this project and the team has started building the base model variant. This is the first try giving to the facemask and after this try the team will see how it looks and what need to change or edit in it for final mask.

The epoxy has filled in the mask. We were not filling the mask to the edges because it may expand after drying and also need to add some more materials over the edges. Therefore, another perimeter has developed where the hot glue has poured in it.

Silicone has weighted properly in two parts and then a silicone roller has made to make it dry. The mold has cleaned with water and soap properly. The hot glue made earlier has divided into

two pieces and the second piece of hot glue has poured over the top and balance nicely. And then foil tape has tapped all around the silicon mold.

We have used some strips of aluminum that we found to create a perimeter around the sculpted mask. Taking a break, during the stirring we sprayed the sculpted mask with the releasing agent on paper plate so that we didn't get releasing agent everywhere. This releasing agent helped in removing the sculpture easily from the mask. The releasing agent selected has less effect over the sculpture and it may need to change in the future mask development.

Figure 63: Facemask making attempt

After performing different attempts of making the facemask it has found that the facemask developed is not as clear and clean that it has to be. So, it has decided to use the pre-fabricated mask and put all the components in that mask. As the team has decided to use the pre-fabricated mask so after getting the mask, it has then modified and installed with all the components required for the project. A hole has drilled in the mask for the modification purpose, and then a silicon tube has passed through that hole for the reason to pass different wires from it. The silicon tube will insert with different electric wires and also a small silicon tube inserts in the main tube. This silicone tube is using to connect the pressure transducer with speaker and fan, and the main tube passes the wires that connects for the Arduino, fan, speaker and microphone. The tubes have then filled with the glue to fix them properly.

Figure 64: In line Tube in Mask

After that the tubes have cut down and filled the sides with the glue in such a way that it will not get block accidently. After that a line has drawn around the center portion of the mask for fitting the

filters and exhaust. From the line, the mask has cut, and then the borders have sewed from where it has cut and folded with glue. And then the exhaust has fitted with the filter. In order to make the mask adjustable in size, different sizes of strips have developed that can set according to the size of face hence the facemask will adjust properly over different faces with these different straps.

Figure 65: Straps of different sizes

In order to make further clear, these straps have made with different colors, so each color is showing a different size strap and the user can easily recognize the suitable size strap from the color. For making the mask to fit in a better way and avoid any leaking, a seal has used by using the adhesive back foam pieces that are into two shapes, that will be quite effective and it can remove as well if needed.

Furthermore, a hole has drilled in the back of the device for the purpose of turning the Arduino power on and off. For this purpose, the push button has used and this push button can press down for on and press again to turn off the Arduino. This button needs some sort of tool like sim removal tool that can push the button easily. And the filter template has developed which then fix in the exhaust cases to make the facemask supportive for inhale and exhale purpose.

Figure 66: Filter Template

The final product has ready yet and has shown below

Figure 67: Final Product

Figure 68: Final Facemask

6.1 Design Changes in Second Semester

6.1.1 Design Iteration 1: Change in Mask discussion

After the few attempts made in building the mask, it has decided to use the pre-fabricated mask for the project, because the pre-fabricated mask available is of fine quality and the amendments can easily make in that face mask and also all the components can easily attach with that facemask so that is the reason this decision has made in second semester, during the implementation phase. This is the only change which has made in the design, remaining all the things have kept same, after getting the pre-fabricated mask, all the components have installed in it in the same manner it has decided before. The facemask prepared by the team has shown below

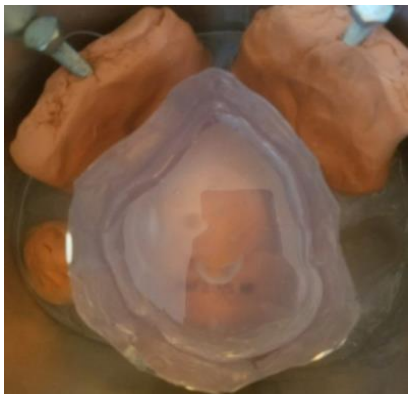

Figure 69: Facemask Attempt

It is clear from the above picture that facemask was not preparing in well defined form, therefore it has decided to use the pre-fabricated facemask.

7 RISK ANALYSIS AND MITIGATION

The team has mititaged few potential failures found in the design and these failures have mititaged mostly through the use of recommended products and ordered most of the products from the well known brands and when the parts have arrived, team has observed them critically and then test each of them through different ways, like materials have tested through tensile strength as well and electronic components have tested through different inputs and meters hence all the components have tested to mitigate the failures as much as possible.

7.1 Potential Failures Identified First Semester

In this section the critical failures of the device area explaining. First of all, the possible failures that can appear in this project have listed below in the FMEA.

Table 9: FMEA

Part # and Functions	Potential Failure Mode	Potential Effect(s) of Failure	Severity (S)	Potential Causes and Mechanisms of Failure	Occurrence (O)	Current Design Controls Test	Detection (D)	RPN	Recommended Action
1 Controller									
1.1 Controller Brun	Burning of Controller	Disconnection with Drone	7	1. Bad quality of controller	4	1. Over Voltage Test	4	112	Check the quality of controller
1.4 Controller Body	Breaking of Body	Cracks and bends	4	1. Bad quality of controller	3	1. Over Pressure Test	3	36	Check the quality of controller
2.2 Filter Break	Breaking of filter	Cost increase	8	1. bad quality of plastic 2. Poor filter	4	1. Pressure Test	5	160	Check multiple filters
2.4 Filter Holes	Dust Stuck in holes	Inhalation problem	6	1. small holes	4	1. Air pressure test	4	96	Check the holes
2.9 Motor Insulation	Burning of Insulation	Trouble in running the motor	4	1. Bad quality of plastic insulator	5	1. Over Voltage Test	4	80	Check the quality of Insulator
3.1 Arduino Board	Burning of board	shorting of circuit	5	1. unsecure circuit lining	7	1. Over Voltage Test	5	175	Check the circuit lining
3.2 Arduino Pins	Breaking of Pins	Over Pressure	5	1. Pins not inserted Correctly	7	1. Over Pressure Test	4	140	Check the pins
3.4 Arduino Connections	Failed to connect	Code Issue	6	1. code fixing	7	1. Code fixing problem	4	168	Check the code resetting
4.3 Battery	Burning of battery	Over Voltage	5	Bad quality of battery cells	5	1. Over Voltage Test	5	125	Check battery quality
4.8 Battery Low output	Less voltage appears at the output	Cells burning	5	Bad quality of cells	4	1. Over Voltage Test	4	80	Battery check quality

7.1.1 Potential Critical Failure 1: Filter Particles Holes

The particles can stick into the holes of filter and that will cause trouble in inhaling the oxygen. And this can resolve by cleaning the filter with time by time and if the filter gets too dirty and will not clean for long time then it will have to replace that will cost more, therefore the critical failure can avoid by cleaning the filter on regular intervals.

7.1.2 Potential Critical Failure 2: Motor insulation burning

The fan is using the motor and the motor of the fan uses the insulation and this insulation can burn and the effect of this burning is that it will cause the motor to stop working. Hence insulation can cause the whole motor to burn therefore it is important to keep check on the motor insulation so that motor will not burn otherwise motor will have to install again and that will cost extra as well. And in order to avoid this failure a close check on the fan is important.

7.1.3 Potential Critical Failure 3: Motor wire

The wiring using inside the motor with the battery can burn and this can stop working of the whole electronic setup. This failure can even burn the mask as well so it is better to put the wiring with the proper insulation so that it will not burn and also keep the check of battery voltage and current so that no over flow of current will appear to burn the wire.

7.1.4 Potential Critical Failure 4: Arduino Board

Arduino board can burn and the reason could be either shortage of lining of the circuit present over the board, and that will cause the short circuit therefore, it is important to keep the Arduino board properly safe from any external wiring or metal to avoid any short circuit. If this failure happens, the Arduino board have to install again, that will cost extra and hence to avoid such failure proper insulation and covering of Arduino board is important.

7.1.5 Potential Critical Failure 5: Arduino Pins

The pins of the Arduino can break and to avoid such failure use the Arduino board with great care. If the pins will break, then new Arduino has to buy and install again, it will cost more as well. And to avoid any such failure it is important to use the Arduino with care.

7.1.6 Potential Critical Failure 6: Arduino Connection

The connection of Arduino can fail because of interfacing of Arduino with the other units and the code may not work properly because the connection with the computer fails and code will not load properly. Hence with this possible failure the device will stop working, and to avoid this failure Arduino connection need to check again and again and properly connects so that such failure will not appear.

7.1.7 Potential Critical Failure 6: Battery Burning

This is another failure that the battery will burn, and if the battery will burn, it will stop the device operation and hence in that case it is important to replace the battery and to avoid this failure the battery has to charge properly and must not over charged and discharged fully.

7.1.8 Potential Critical Failure 7: Battery Low Voltage

The voltage level provides by the battery can reduce and in that fact the failure of devices uses in the mask can fail to operation and to avoid this failure, use the good quality battery and charge the battery properly so that no over voltage or low voltage will appear.

7.1.9 Potential Critical Failure 7: Controller Burning

There is another failure that can appear and that is burning of failure. In this case, if the failure burns, then it will not let the device working and to avoid this failure keep the controller in a safe position where no short circuit will cause the board to burn.

7.1.10 Potential Critical Failure 7: Filter Break

Another failure is the breaking of body of filter and this can happen if the mask will fall down and in that case the filter has to replace with the new one. While to avoid this failure, it is important to use the mask with care.

7.2 Potential Failures Identified This Semester

The potential failure identified in this semester have listed below:

7.2.1 Potential Critical Failure: Braking Straps

The straps have not identified before as potential failure but when the team has ordered the straps, and have seen them then it has realized that these straps can break because of over stretching, therefore the team has mitigated this issue by ordering different sizes of straps for different faces hence the correct strap will use for the face and in this way it will not over stretch and hence the chance of breaking will no more. And to further mitigate the problem that how the correct size strip will find, team has made different straps in different colors and hence it will become easy for the user to select the right size strap for him.

7.2.2 Potential Critical Failure: Silicone Pipes Breaking

This failure has not been recognized in the first semester but now the team has found this potential failure, and that is breaking of connection between the silicon tube and facemask and it can happen if the tube stretches extra with some pressure and it will detach from the facemask therefore, the team has mitigated this problem as well by putting the silicon at the joint to fix it properly.

7.3 Risk and Trade-offs Analysis

Most of the risks have defined already and it was clear from the critical failures that all the failures are interlinking with each other. So, it is clear that all these are the risks and in case of any failure the device will able to work like if the motor will stop working, the air will stop coming into the mask, in case of battery burning, the device will not get any voltage and hence it will be useless and in case of controller burning the device will not operate as well. Hence, in all the cases the device will not operating anymore. So, the risk is that device will not keep working in case of any failure.

In order to trade off with the risk, the only option is that use the device without any electronic device during the failure time and replace the component afterwards. The tradeoff analysis shows that if the device will use without any electronic device, it will cause trouble to the user but it

will save the user from corona virus hence it can state that using of device without the electronic component can be a tradeoff for the risk, if the risk appears. Otherwise, there are very few chances of such failure happening with this device therefore doing any other trade off to mitigate the risk is not a good option.

8 ER Proofs

The team has completed the project and after the completion of project it was necessary for the team to verify the design and see if it has fulfilled the requirements or not. Therefore, engineering requirements can verify through different tests. For this project, the verification of engineering requirements have done through the physical testing which includes the laboratory tests, physical feet scales have used and operating the device for longer duration.

8.1 ER Proof #1 – Length

It can test by using the feet scale. The test can perform in any conditions inside the room. Feet scale is available in all the labs and it can easily perform the test. This test has performed after the project was ready and it has tested within the lab to confirm that the length was lower than 8 inches. A feet scale has used and measured the length from one edge to the other edge and noted down the value in inches.

8.2 ER Proof #2 – Battery Time

To test the battery time, full charged the battery and then keep the mask running with full load and note down the time using the mobile phone. This task can perform inside the room without any other equipment and hence it has performed while testing the mask. The battery has fully charged and after that it has used for longer duration and all the components have been operating during that time and when the battery got discharge the time has noted and hence from this testing it has confirmed that the battery time is longer than 8 hours.

8.3 ER Proof #3 – Expiration Rate

This can test by using the anemometer available in the chemistry lab to test the air flow measurement. The device has to take in the chemistry lab to perform this test and it has performed. For performing this test, the team has contacted the lab TA and asked to operate the anemometer to check the expiration rate by checking the air speed of fan. This test has conducted under the lab circumstances and found that the expiration rate was more than 6 liter per minute and it took only half an hour to perform this test.

8.4 ER Proof #4 – Tidal Volume

To test this engineering requirement, use Spirometer. This device is available in the civil lab, and to perform this test the device has to take in the civil lab. Hence the team has taken the device to civil lab, where the spirometer was available and asked the lab operator to check the tidal volume of the mask by placing it in spirometer. The test has performed under the lab conditions and found that tidal volume was in the vicinity of 0.5 liter.

8.5 ER Proof #5 – Transparent Material

To test it, need clarity meter also called transparency meter. This device is available in the mechanical lab. For performing this test, the material for making the device has to take in the mechanical lab for performing the test. The team has taken the pre-fabricated mask in the mechanical lab, and even it was known that transparency is less than 2, but still it has tested in the clarity meter and it was correct, transparency was lower than 2.

8.6 ER Proof #6 – Weight

To test this ER, need a weight machine which is easily available in all the labs, including chemistry lab and mechanical lab. This test has performed after the device has completed and when the device has

completed, the whole setup has taken into mechanical lab, and then each the mask weight has calculated over the weight machine, while the other components like amplifier has not considered in it because it is present outside the mask and not hanging over the face. The weight of wearing mask was less than 50 g.

8.7 ER Proof #7 – Battery Capacity

The capacity of battery can determine by multi-meter which is available in the electrical lab. So, the device or battery need to take into the lab and perform the test. The team has taken only the battery in the lab, after the battery has arrived and before installing it. There was digital multi-meter available and the TA was present over there. It has asked by the TA to check the battery rating through the meter and after measuring the rating it was around 2500 mAh, and hence it has found correct so after that it has installed in the device.

8.8 ER Proof #8 – Filter Size

The size of filter can measure with the inches scale, and that scale is available in the labs. The filter template made, was then measured through the inches scale and it was found that size is smaller than 300 x 300 mm, then it has installed in the facemask.

8.9 ER Proof #9 – Particulate Size

The particulate size can measure through the micron microscope that is available in the chemistry lab. After the filter has designed it has then taken into chemistry lab and measured the particulate size, which was found lower than 2.5.

In this way, all the ER’s have tested and verified, so it can state that all the engineering requirements have fulfilled by the design.

9 LOOKING FORWARD

The project is ready now and it is working perfectly. In order for the client make improvements in it, then manufacture the mask with the complete setup through the machines, because the hand made product is working and operating perfectly but to make it better, manufacture this device in the machine which will provide a clear shape and each joint will perfectly fabricate, like the silicon tube attachment with the mask, and the fitting of filter in the mask etc. all these things will appear in good shape when the manufacturing will be done in proper machine.

9.1 Future Testing Procedures

In testing procedure, it will define the process to test each engineering requirement. Testing procedure is important because it clarify whether the engineering requirement has met by the design or not, or to which extent the engineering requirement has met by the design. This is also the reason that engineering requirements have developed from the customer requirement because customer requirements cannot measure but engineering requirements can measure through different processes and through different equipment's. In this section each engineering requirement testing process will describe with the equipment required for it and the schedule to perform that test.

9.1.1 Testing Procedure 1: Length

Length of the mask is an important engineering requirement because it will tell whether the mask covers the face properly and protect the face from getting effected from corona virus.

9.1.1.1 Testing Procedure 1: Objective

The objective of performing this test is to determine whether mask has specified length described in the engineering requirements or not. This test will perform easily in any lab because it just needs to measure the length of the mask and that can measure through any feet or inch scale. The mask will measure from top to bottom.

9.1.1.2 Testing Procedure 1: Resources Required

To perform this test, it only needs a foot scale to measure the length of a mask. And it can perform inside any lab, as feet scale is available in all the labs, and also it can perform at any place.

9.1.1.3 Testing Procedure 1: Schedule

This test will perform after it will complete. The product will be ready and then this test will perform during the day time.

9.1.2 Testing Procedure 2: Battery Time

Battery timing is important to perform to see how long the mask will keep active and hence it will finalize whether the engineering requirement has met by the design or not.

9.1.2.1 Testing Procedure 2: Objective

To perform this test, it needs the battery to be fully charged and then count the time and the reason for performing this test is to check if the battery can perform up-to the mark or not.

9.1.2.2 Testing Procedure 2: Resources Required

For performing this test, it needs the timer available in the cell phone. And this test can perform at any point, and to perform this test it needs the battery to fully charge and then use the mask with full load and check how long the battery will keep running.

9.1.2.3 Testing Procedure 2: Schedule

This test will also perform when the device will complete and it will test during the day time and probably it needs to perform in the morning so that 8 hours can count properly. This test will perform when the device will ready to use.

9.1.3 Testing Procedure 3: Expiration Rate

Expiration rate tells the amount of air flowing into the mouth through the external source. This expiration rate is important in this mask, so that the person wearing the mask will not feel uncomfortable because of lack of oxygen available for inhaling.

9.1.3.1 Testing Procedure 3: Objective

The objective of performing this test is to check if the person will get enough air inside the mask for inhaling purpose. The expiration rate will test by determining the air flow rate, and that has to be 6 liter per minute at least so that person can get enough oxygen for the body.

9.1.3.2 Testing Procedure 3: Resources Required

To perform this test it needs anemometer device, and this device is available in the chemistry lab. In the lab, the mask has to place by anemometer where the inflow will check by the anemometer and the anemometer will tell what is the inflow rate of air. If it is around 6 liter per minute or above then the design is working perfectly fine according to the requirements.

9.1.3.3 Testing Procedure 3: Schedule

This test will perform when the project will finish, the project will complete in April so this test will perform after it will complete. And it will perform in the chemistry lab during working hours.

9.1.4 Testing Procedure 4: Tidal Volume

Tidal volume is important measure for this case as it will tell the air available inside the mask and it has to be 0.5 liters.

9.1.4.1 Testing Procedure 4: Objective

The objective of this test is to determine the tidal volume inside the mask. And if the tidal volume is less than 0.5 liters, it will cause trouble to the person wearing the mask.

9.1.4.2 Testing Procedure 4: Resources Required

To perform this test, it needs the spirometer that is available in the Civil lab. And it need the mask to put inside the spirometer to determine the tidal volume.

9.1.4.3 Testing Procedure 4: Schedule

This test will perform when the project will finish, the project will complete in April so this test will perform after it will complete. And it will perform in the civil lab during working hours.

9.1.5 Testing Procedure 5: Transparent Material

Transparent material is the one that will use to build the mask and if the mask is transparent enough to see, then non-verbal communication will be easy to perform in this mask. Therefore, this mask has to be transparent with the transparency level up to 2.

3.1.5.1 Testing Procedure 5: Objective

The objective of this test is to check whether the material is enough transparent to see what is happening inside the mask. And this transparency level will help the user doing non-verbal communication easily.

9.1.5.2 Testing Procedure 5: Resources Required

To perform this test, it needs the clarity meter which is also called transparency meter. This device is available in the mechanical lab. For performing this test, the material for making the device has to take in the mechanical lab for performing the test.

9.1.5.3 Testing Procedure 5: Schedule

This test will perform when the project will finish, the project will complete in April so this test will perform after it will complete. And it will perform in the lab during working hours.

9.1.6 Testing Procedure 6: Weight

Weight is an important factor for this mask, because if the weight is heavy then it will difficult to wear the mask for long time and it will irritate the user as well.

9.1.6.1 Testing Procedure 6: Objective

For the device, its weight needs to measure and verify that it must be lower than 50 lb. so it can easily wear for long time without irritating the user. And to perform this test it needs the simple equipment to confirm if the weight is lower then 50 lb.

9.1.6.2 Testing Procedure 6: Resources Required

This test needs the weight machine available in all the labs, and the sensitive weight machine is available in the chemistry lab or mechanical lab as well. Hence place the device on the weight machine and measure the weight of the device.

9.1.6.3 Testing Procedure 6: Schedule

This test will perform when the project will finish, the project will complete in April so this test will perform after it will complete. And it will perform in the lab during working hours.

9.1.7 Testing Procedure 7: Battery Capacity

Battery capacity tells how much the battery can bear the load and how long the battery can sustain with that load.

9.1.7.1 Testing Procedure 7: Objective

Battery capacity need to determine for this project because it is essential to find if the battery can bear the enough load and the required battery capacity is 2500 mAh. And hence if the battery is more than 2500 mAh, it will be fine for the project.

9.1.7.2 Testing Procedure 7: Resources Required

The source required to perform this test is multi-meter which is available in the electrical lab. And battery will bring out of the case from the device and it will connect with the multi-meter to measure the battery capacity.

9.1.7.3 Testing Procedure 7: Schedule

This test will perform when the project will finish, the project will complete in April so this test will perform after it will complete. And it will perform in the lab during working hours.

9.1.8 Testing Procedure 8: Filter Size

The filter size is important in the design because it will manage the whole inhalation and exhalation process and it will provide the fresh air as well from the outside. So the size of filter is important in the mask.

9.1.8.1 Testing Procedure 8: Objective

The objective of performing this test is to find the filter size and this filter size can determine easily by measuring the length and width of the filter. It has to be less than 300 x 300 mm so that it will not cover the whole mask.

9.1.8.2 Testing Procedure 8: Resources Required

The required source for this test is scale in foot, that will use to measure the length and width of the filter.

9.1.8.3 Testing Procedure 8: Schedule

This test will also perform when the device will complete and it will test during the day time.

9.1.9 Testing Procedure 9: Particulate Size

The particulate size is the hole of the filter through which the air will pass in to the mask and this hole should be of enough size that corona virus particles cannot enter into the mask otherwise the mask is useless.

9.1.9.1 Testing Procedure 9: Objective

The objective of performing this test is to basically determine the particulate size of the filter and it has to be less than 2.5. Otherwise, the corona particles can enter into the mask.

9.1.9.2 Testing Procedure 9: Resources Required

For performing the test, it needs the microscope that will use to measure the particulate size and this is available in the chemistry lab. The filter will place under microscope and it will measure.

9.1.9.3 Testing Procedure 9: Schedule

This test will perform when the project will finish, the project will complete in April so this test will perform after it will complete. And it will perform in the chemistry lab during working hours.

9.2 Future Work

The project has completed like it has everything but there is always a room of improvement in anything and same is the case here as well. The facemask can further enhance with the improvements like amend the program and create a system that can provide easy access for eating and drinking. This facilty should provide in such a way that the mask need not to remove but at the same time user can eat and drink easily.

Another improvement which can make in the project and this improvement is protecting the eyes with the face. Like the face covers the nose, and lips, it will cover the eyes and it will have the same features. These two improvements can make in the design and the project can recreate with these two features along with the other features.

Testing procedures results in previous section can may alter the changes in the design like the HEPA filter size may need to change in the design, fit a smaller HEPA filter in the design that will give a better look to facemask and also it will less reshape the actual facemask, so, the size of HEPA filter need to reduce. The overall weight need to reduce for the wires including the silicon tube present with the facemask. The reason is that with the presence of tube, the facemask pushes down and it can irritate the user and the user will have to set the facemask again and again. Therefore, the weight has to reduce for the external components that puts their weight over the facemask. These are the few things that need to consider for the future work and by doing these changes, the facemask will become a perfect device to use for.

10 CONCLUSIONS

The purpose of the project is to design such a mask that will use for protecting from Covid-19 and also helps in breathing easily. The mask has designed that is easy to wear for long time and it helps in breathing with the presence of respiratory system of inflowing oxygen through the fan and through the filter as well. The requirement of the project was to design a mask through which non-verbal communication is possible and it can use some electronics to help in communicating with others verbally through the use of mic and loud speaker. It can wear for long time without facing any trouble of inhaling and exhaling and it also protect from carrying any corona virus and along with that also keep safe from the dust. With all these features present in the device a design has made that covers the face properly and provides a filter that control the dirt particles but allow the regular air to goes in. And it also provides the pressure transducer to check the inside and outside pressure and when the pressure inside the mask drops, a fan will provide the respiratory flow of air into the mask and hence the inhaling and exhaling of oxygen will be easy and user will not feel any difficulty in wearing the mask. Along with that a small mic and speaker is present on the mask to do the communication easily. The selected design has a filter at the front side and speaker is present at the at the bottom side of the mask. The selected pressure transducer for the design is MPXV7002DP while the controller selected is Arduino Nano, and SparkFun Mic and Speaker has selected to put in the mask, and HEPA Filter is using in the mask. Currently the team is working on the controller and writing the code for pressure transducer and communicating the pressure transducer with the Arduino and observing the response of transducer.

The project has implemented and the facemask is ready to use and it is a transparent mask which makes the communication easy and the presence of speaker and mic further enhance the communication and by using this facemask, the user can easily show his or her expression and the user can wear this facemask for longer period of time. While the presence of battery and the amplifier that attaches with the facemask but buckled at some other points can help in doing the communication easy and can wear for long period of time.

The risk and trad-off analysis has performed and from the analysis it is clear that the device has to use with great care otherwise chances of damage will increase and for the failures, some components can fail in the device but the chance of failing is quite low, while in case of any failure the trade-off is to wear the mask without suing the electronic system and remove the mask after sometime to get some fresh air, until the respective component will reinstall.

10.1 Reflection

The project has done which ensures of public safety as well, like nothing has used which can cause damage to anyone within the surrounding. The whole project has made up with the safe material and the project itself is safe to use. The material used in the project is not affecting the environment, it is environmentally friendly and not releasing any kind of trash in the surrounding which makes the environment dirty. During the designing of project, it has ensured that safety is first priority, and the project must adopt the cleanliness of environment as well. Rather the project itself is about keeping the user safe from the environmental effects like polluted air will

not let inside the mask and user will get only clean air because of the presence of filter and also the mask will save the user from Covid-19 particles.

In order to ensure the designing was safe, it has tested multiple times from the start of manufacturing till the end. Before that, it has analyzed visually that is there anything sharp cut that can harm the user or anyone else. After in implementation phase it has tested multiple times by placing the mask over the face and see if it is hurting any part or not. The selected material of mask was soft plastic to ensure the safety. And the pre-fabricated mask has selected because it has a proper shape and all the edges are in rounded shape and all the edges have described in well mannered blended form which shows the safety has set at first during this designing.

In order to ensure the environmentally friendly the team has set the design specifications and analyzed each requirement and then see is there anything in this experiment which is going into the atmosphere and causing pollution. But as there wasn't anything present so it has ensured that the project is environmentally friendly

10.2 Post Mortem Analysis of Capstone

The post mortem analysis of this capstone project has done and it has presented below in two different sections.

10.2.1 Contributors to Project Success

The project has completed successfully and all of those who puts their full efforts and helped the team in building the project, resolving the issues faces in the project, all those persons should be named here being a part of contributors that make the project successful. First of all, the team has done good job in the project, all the team members have played their role in making this project successful, without their full efforts and hardworking it was never possible to achieve the successful project. All team members were fully cooperated with each other and worked as a team, and shown the team spirit while doing this project and because of their efforts the project has done on time and it has fulfilled all the requirements of the project as well.

Apart from team members, client has played great role in making this project successful. He was there all the time to ask anything and helped the team in difficult times. The course instructor has helped the team in figure out the problems and therefore the client and instructor has pushed the project to this level.

The main goal of the project was to build such a facemask which helps in doing the clear communication and makes it easy for the user to inhale and exhale. This project has achieved successfully and the all the engineering requirements have met by the design and all the testings have done which shows the project is properly providing the way to do the communication and also easy to use for long period of time. Achieving of the goals exactly it was reqired is itself a contribution to the project success because it enhances the moral of the team members and also give them a chance to work professionally.

There were some ground rules defined in the team charter and the success achieved by this project is by following those rules. One of the reasons is to obeying the rules and follow what has said to them played a major role in achieving the project success.

In the team charter it has stated to follow the rules and obey the time lines and perform the things on time. All the team have followed the team charter and has completed all the tasks before the time and completed all the tasks perfectly. On the other hand, another thing which contributed in the project success is time management. The team has managed the time and able to finish the project on time. The time management was a big issue for completing the project on time but with the great management it has done so time management has played a great rule in completing the project successfully.

In the team charter, another has mentioned about making the group where each member can talk and can discuss about the project. The team has made that group and because of that group it has been possible for the team to discuss different things related to the project and hence it played a great role in completing the project successfully. Furthermore, in the team the team goal has mentioned and the project has achieved that goal by following the rules, regulations and requirements.

10.2.2 Opportunities/area for improvement

The project has completed like it has everything but there is always a room of improvement in anything and same is the case here as well. The facemask can further enhance with the improvements like amend the program and create a system that can provide easy access for eating and drinking. This facilty should provide in such a way that the mask need not to remove but at the same time user can eat and drink easily. Another improvement which can make in the project and this improvement is protecting the eyes with the face. Like the face covers the nose, and lips, it will cover the eyes and it will have the same features. These two improvements can make in the design and the project can recreate with these two features along with the other features.

Testing procedures results in previous section can may alter the changes in the design like the HEPA filter size may need to change in the design, fit a smaller HEPA filter in the design that will give a better look to facemask and also it will less reshape the actual facemask, so, the size of HEPA filter need to reduce. The overall weight need to reduce for the wires including the silicon tube present with the facemask. The reason is that with the presence of tube, the facemask pushes down and it can irritate the user and the user will have to set the facemask again and again. Therefore, the weight has to reduce for the external components that puts their weight over the facemask. These are the few things that need to consider for the future work and by doing these changes, the facemask will become a perfect device to use for.

Use of soft material for the straps so that it will not hurt the ears is another improvement which can make in the design and it will help the user to keep the mask for longer period of time and it will help the user not to get irritated. Another possible improvement is removing the wires that externally connects the components with the mask and make the whole system as wireless, so no more wire will be showing around.

7 REFERENCES

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APPENDICIES

APPENDIX A – Bill of Materials

Table 10: Bill of Materials

Product	Purpose	Material	Unit Cost	Cost
Epoxy Resin	For adhesiveness	Glue material	$34.99	$34.99
Plasti Dip Black	For shaping	Aluminum Foil	$21.95	$21.95
Acetone	Remover	Acid	$8.79	$8.79
Airfit Cushion	Filter	Plastic	$14.01	$14.01
Resin Casting	Sealing	Fabric	$14.99	$14.99
Disc Pad	Sealing	Paper	$9.99	$9.99
Adhesive Foam	Sticking	Foam	$13.85	$13.85
Clay	Facemask Design	Clay	$18.99	$18.99
Black Cotton	Sealing	Fabric	$16.99	$16.99
Sponge Foam	Edges	Foam	$16.80	$16.80
Direct	Cliping	Plastic	$9.99	$9.99
Product	Purpose	Material	Unit Cost	Cost
Neoprene	Rolling	Fabric Foam	$11.00	$11.00
Facemask	Model Mask	Plastic	$15.89	$15.89

Amplifier	Voice Loudness	Plastic Silicone	$35.99	$35.99
Snap Button	Stich	Metal	$11.99	$11.99
Face Shield	Model Mask	Plastic	$23.39	$23.39
Mannequin Head	Model Head	Plastic	$22.99	$22.99
USB Fan	Air Pressure	Plastic	$7.90	$7.90
Cooling Fans	Air Pressure	Plastic Silicone	$14.00	$14.00
Transparent Mask	Model Mask	Plastic	$15.99	$15.99
Quilting Fabric	Covers	Fabric	$12.00	$12.00
Filter	Filtration	Plastic	$34.99	$34.99

Air Filter	Filtration	Plastic	$12.99	$12.99
Life casting Alginate	Plaster for model	Plastic Cement	$39.36	$39.36
Blower Fan	Air pressure	Plastic	$9.99	$9.99
Raspberry Pi	Controller	Silicon	$9.49	$9.49
Sheet Rolls	Sheet	Fabric	$14.80	$14.80
Pads	Padding	Fabric	$16.13	$16.13
Silicon Sealant	Sealant	Chemical	$16.50	$16.50

Ribbon Band	Padding	Fabric	$6.99	$6.99
Total				$585

APPENDIX B – PRESSURE SENSOR CODE

```
unsigned long prevTime, currTime;
unsigned long OneHourCounter;
const unsigned long OneHour = 72000; // 1*3600*1000/50=72000
byte LEDR = 11;
byte LEDG = 12;
byte LEDY = 13;
enum Color { RED, GREEN, YELLOW };
Color clr ;
int val;
int PressZero;
void setup() {
  // put your setup code here, to run once:
  pinMode(LEDR, OUTPUT);
  pinMode(LEDG, OUTPUT);
  pinMode(LEDY, OUTPUT);
  Serial.begin(115200);
  prevTime = millis();
  OneHourCounter = 0;
  clr = GREEN;
  PressZero = GetZero();
  UpdateLEDs();
}

void loop() {
  // put your main code here, to run repeatedly:
  currTime = millis();
  //main reading every 50 ms
  //after reading a value transform it to pascal
  //and remove the possibel zero offset
```

```
  if (currTime - prevTime > 50)
  {
    val = analogRead(A0);
    val = ConvertToPascal(val);
    val = val - PressZero;
    Serial.println(val);
    OneHourCounter = OneHourCounter + 1;
    prevTime = currTime;
  }

  //One hour counter.
  if (OneHourCounter == OneHour)
  {
    OneHourCounter = 0;
    UpdateState();
    UpdateLEDs();
  }
}

void UpdateLEDs() {
  //Turn LEDs properly according to the current state.
  switch (clr)
  {
    case RED:
      digitalWrite(LEDR, HIGH);
      digitalWrite(LEDG, LOW);
      digitalWrite(LEDY, LOW);
      break;
    case GREEN:
      digitalWrite(LEDG, HIGH);
```

```
      digitalWrite(LEDR, LOW);
      digitalWrite(LEDY, LOW);
      break;
    case YELLOW:
      digitalWrite(LEDY, HIGH);
      digitalWrite(LEDR, LOW);
      digitalWrite(LEDG, LOW);
      break;
    default:
      digitalWrite(LEDR, LOW);
      digitalWrite(LEDG, LOW);
      digitalWrite(LEDY, LOW);
      break;
  }
}
void UpdateState() {
  //switch the led colors in the following manner
  //Initialy LED still green for one hour.
  //then yellow for another hour
  //after it enter the RED state untill RESET
  switch (clr)
  {
    case GREEN:
      clr = YELLOW;
      break;
    case YELLOW:
      clr = RED;
      break;
    default: break;
  }
```

```
}
int GetZero(){
//used as a calibration for the zero pressure at the
//begin of the program
  int S=0,S1=0;
  int i,temp;
  for (i=0;i<64;i++)
  {
     temp = analogRead(A0);
     S = S + (temp >> 6);
     S1 = S1 + (temp%64);
     delay(50);
  }
  S1 = S1 >> 6;
  S = S + S1;
  S = ConvertToPascal(S);
  return S;
}
int ConvertToPascal(int x)
{
  //Formula: Pascal = 800*5*val/1024 - 1600;
  // = Pascal = 3.9063*val - 1600;
  // = 3 + 1/2 +1/4 +1/8 + 1/32
  //val is the value of the ADC
  int y,temp;
  //y = 3x
  y = 3*x;
  //y = 3.5*x (1/2)
  temp = x>>1;
  y = y + temp;
```

```
  //y = 3.75*x (1/4)
  temp = temp>>1;
  y = y + temp;
  //y = 3.875*x (1/8)
  temp = temp>>1;
  y = y + temp;
  //y = 3.9063*x (1/32)
  temp = temp>>2;
  y = y + temp;
  y = y - 1600;
  return y;
}
```