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1 Introduction

Air purifier is a device used to improve the air quality in a given closed environment. Existing air purifiers in the market provides 3-layer filtration system, along with this they incorporate a mobile app which monitors the functioning of the device and provides data in real time. Our air purification system provides all the features offered by the existing air purifiers in addition we also offer other key features unique to our air purification system at a significantly lower cost. Our air purification system is mainly based on the intercommunication of the devices in a room which aids in air purification process. This includes controlling the ceiling fan and ventilating system. Ceiling fan helps in circulating air around the room, so air even at the periphery of the room could be purified. Ventilation system control includes the opening and closing of a window with respect to the functioning of the air purification system. HEPA (High Efficiency Particulate Arrestor) filter is the type of filter used in our air purification system. HEPA removes particles above 0.3-micron size with an efficiency of 99.1%. We use smart technology with numerous sensors which measures the amount of pollutants in air in real-time and the control system controls the switching of the purification system as well as speed of its operation. IoT is incorporated in this system, this helps in sharing all information along with maintenance details to any device connected to it. Air purifier uses a 3-layer filteration system. A methane sensing and alarm unit is also included for monitoring the leakage of methane.

2 Requirement Analysis

2.1 Societal Need

With the turn of the twenty first century, outdoor activities are on a decline. More and more activities and amusements are specifically indoor. The time people spend in indoor activities accounts for eighty percent of their total life time. Indoor air quality has a great effect on human health. At present, widely used environmental monitoring equipments in the market is designed only to monitor the environment. They do not support appliances such as humidifier and air purifier. Therefore, it is impossible to improve the quality of environment according to the results from real-time environmental monitoring equipment. Based on this requirement, the IoT based smart air purification system designed in this paper not only helps people to be well aware of environmental parameters whenever necessary but also provides extended interfaces for other devices. With these extended interfaces, the control for other household equipments, which aids in air flow of the room would be achieved (ceiling fan and ventilation control). Then excellent indoor air quality can be ensured. The low cost of the device enables customers from any strata of the society to easily afford our air purification system.

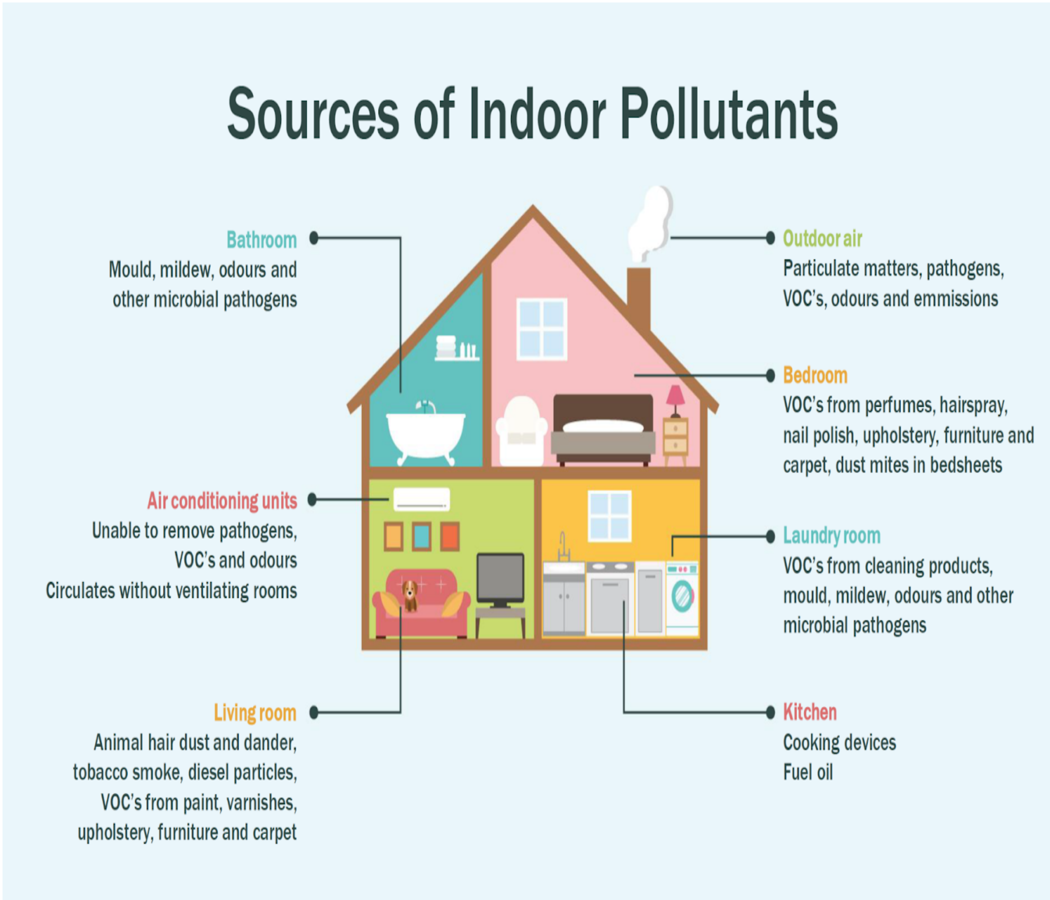

Figure 2.1: Sources of Indoor Pollutants

2.2 Target Customers

Target customers for an air purification system includes office workers, children, the elderly, people suffering from respiratory diseases, people living in large metropolitan cities etc. Office workers spent most of their working hours indoors. These people are always exposed bad indoor air quality and are likely to develop chronic lung conditions in the near future. Children are in their developmental stages so their immune system is more fragile, and their breathing rate is 50 percent higher than that of adults. It makes them more vulnerable to indoor air pollution. With a long term inhalation of smoke, harmful gases, bacteria and viruses etc. it is easy to induce a variety of diseases, in addition poor indoor air quality also attacks the children's body functions for a long term, thereby affecting the normal development of height and intelligence.

The elderly people also do require good indoor air quality. As the body enters its old age, immune system tends to be weaker, this leaves body open to respiratory infections. As we have mentioned before people with respiratory diseases are also affected by poor indoor air quality. According to the survey, 68 percent of the human body's illnesses are related to environmental air pollution. The most common human disease is the respiratory infections, and its symptoms can range from an implicit infection to a life-threatening illness. People living in cities like Delhi where air quality is very poor should also possess air purification systems. The poor outdoor air quality in these cities eventually causes poor indoor air quality.

2.3 Market Feasibility

Outdoor air pollution is a major environmental health problem worldwide, especially in areas with low and middle income. Among all types of pollutants, particulate matter affects more people and attracts increasing attention of researchers recently. Airborne particulate matter consists of solid and liquid, organic and inorganic substances. The recent havoc in Delhi caused by smog and other air pollution related problems have brought air purifiers to the limelight.

Despite the aforementioned problems of outdoor and indoor air pollution, the other side of the coin is the fast technological development of smart structures, smart buildings, and the Internet of Things (IoT). Although there are a variety of air purifiers existing, our air purifier stand out by incorporating a variety of features, which are:

- Smart operation: Automatic on and off by sensing air quality within the room and real time data accessible from mobile using app.

- Energy efficiency: Automatic switching control according to dust sensor output therefore increased efficiency.
- Extended interface: Ceiling fan speed control and ventilation control by the air purifier.
- Cost: Aforementioned features of our air purification system are available at an affordable price range even for lower middle class customers and we all know that middle class people constitutes the major share of population in big cities. So the market risk for our product is well down to zero.

3 Formulation Of Target Specifications From Requirements

3.1 Need-Metric Matrix (QFD) For The Product

Overall QFD of the product is provided with customer requirements as cost, reliability, efficiency, maintainability and ease of use. These requirements are related with technical specifications of the product. Customers, especially in India focuses mainly on how the product provides value for their well earned money. This factor justifies our inclusion of cost as a customer requirement. Inclusion of reliability doesn't need a justification, because it is one of most sought after customer requirements for all products. Reliability in this context is defined as the ability of the air purifier to be functioning at a high performance level through out its life time. Efficiency is another important customer requirement. Efficiency for an air purification system can be defined as the ratio of the maximum purification action produced to the given power input. Maintainability can be defined as the ease in which the product can be maintained. Low maintenance for a product is a very important quality that the customer desires. Ease of use or usability of a product is also included because a good product can be classified as a great product only if the customers can operate them with minimal effort. The most important customer requirements among the aforementioned requirements are cost and maintainability because they are the qualities valued by middle class customers, who constitute most of the target customers. So they are given the highest customer weightage. Ease of use is given the lowest weightage because it is the least important requirement among the given five.

Functional requirements are fast response, energy saving, accuracy and aesthetics. Fast response in this context is referred to as the ability of the purification system to commence purification action swiftly without much delay. Energy saving is a functional requirement which describes how well the purification system takes different measures to save energy. Accuracy is also a functional requirement because it gives us measure of how well the purification system functions without faults or errors. Lastly aesthetics is also an important requirement because products like an air purification system always finds its place in living rooms of homes so they are expected to be aesthetically pleasing. So after QFD analysis we can conclude that accuracy should be given the highest priority while fast response should be given the lowest priority.

3.2 Setting The Target Specifications

3.2.1 Project objectives and goals

The primary objective of this project is to design an air purification system compatible for a future smart home technology. This design includes intercommunication between devices that can aid one another. In this project devices like air purifier, ceiling fan , automated window and a methane sensing unit works in conjunction with each other.

3.2.2 Room Size

The size of room is determined after calculating the rate of purification action capable by the purifier section.

3.2.3 Air Changes per Hour (ACH)

ACH rating is a measure of the rate at which an air purifier purifies the air within the room. It indicates how many times per hour an air purifying device can exchange the air within a room. ACH rating selected = 3X i.e. our device exchanges the air within the room 3 times in an hour.

3.2.4 Clean Air Delivery Rate (CADR)

CADR rating is certified measurement by the Association of Home Appliance Manufactures (AHAM) that shows consumers how well an air purifier can clean the air within a specific room size. It gives an objective standard to evaluate the effectiveness of an air cleaning device.

CADR rating is expressed in CFM (cubic feet per minute) or CMH (cubic meter per hour)

Selected fan has 275 cubic meters of air delivery

ACH rating =3X

275 cubic meters = 9711.53 cubic feet

This is the amount of air cleaned by the air purifier in a single hour.

so the selected room after applying ACH rating should have a volume of

9711.53/3= 3237.1766 cubic feet

3237.1766 cubic feet = 91.66 cubic meters

CADR = volume of air purified per minute

= 9711.53 cubic feet / 60

= 162 CFM

From fig 3.2 we can observe that an air purifier having 150 CFM and 3X ACH rating will optimally work for a 375 sq.ft room.

so we can conclude that our 162 CFM, 3X air purifier will work satisfactorily in a 375 sq.ft room even after accounting for losses.

	Air Changes Per Hour				
CADR	1	2	3	4	5
50	375	188	125	94	75
100	750	375	250	188	150
150	1,125	563	375	281	225
200	1,500	750	500	375	300
250	1,875	938	625	469	375
300	2,250	1,125	750	563	450
331	2,483	1,241	828	621	497
400	3,000	1,500	1,000	750	600
416	3,120	1,560	1,040	780	624

**Smoke CADR

Figure 3.1: Table corresponding to CFM, ACH rating and room size

QUALITY FUNCTION DEPLOYMENT (QFD)

		FUNCTIONAL REQUIREMENTS			
CUSTOMER REQUIREMENTS	CUSTOMER WEIGHTAGE	FAST RESPONSE	ENERGY SAVING	ACCURACY	AESTHETICS
COST	5	**L**	**H**	**H**	**H**
RELIABILITY	4	**M**	**L**	**H**	**L**
EFFICIENCY	4	**M**	**H**	**L**	**L**
MAINTAINABILITY	5	**L**	**L**	**H**	**M**
EASE OF USE	3	**M**	**L**	**M**	**M**
TECHNICAL IMPORTANCE SCORE		117	138	177	138
IMPORTANCE%		20.5263%	24.2105%	31.0526%	24.2105%
PRIORITY RANKING		4	3	1	2

H- STRONG RELATION- 10

M- MEDIUM RELATION- 7

L- WEAK RELATION- 4

Figure 3.2: Overall QFD

4 Block Level Design

4.1 Charging Circuit

We take the supply from a 230V AC source. Next we pass it via a 12V transformer to step the voltage down to 12V. In the next stage, we use a bridge rectifier to convert the AC supply into DC. We use a capacitor filter to filter out the output and use this as the required supply. In implementation, we use an adaptor to acquire the above result from the 230V supply.

4.2 Main Block Diagram

ATmega 328 is a microchip found in Arduino uno microprocessor. We connect both the methane gas sensor as well as the dust sensor to the ATmega. The wifi module ESP8266 is also interfaced with the micro controller. A motor driver IC L293D is connected to the micro controller. A buzzer and a relay is also connected. The sensors sense the amount of dust and natural gas/methane in the air and deliver the values to the micro controller. According to these values, the micro controller drives the motor driving IC to operate the two motors governing the action of the window. If the gas sensor produces a high output, then the micro controller sends a signal to the buzzer which activates it, thus producing an alarming sound. According to the

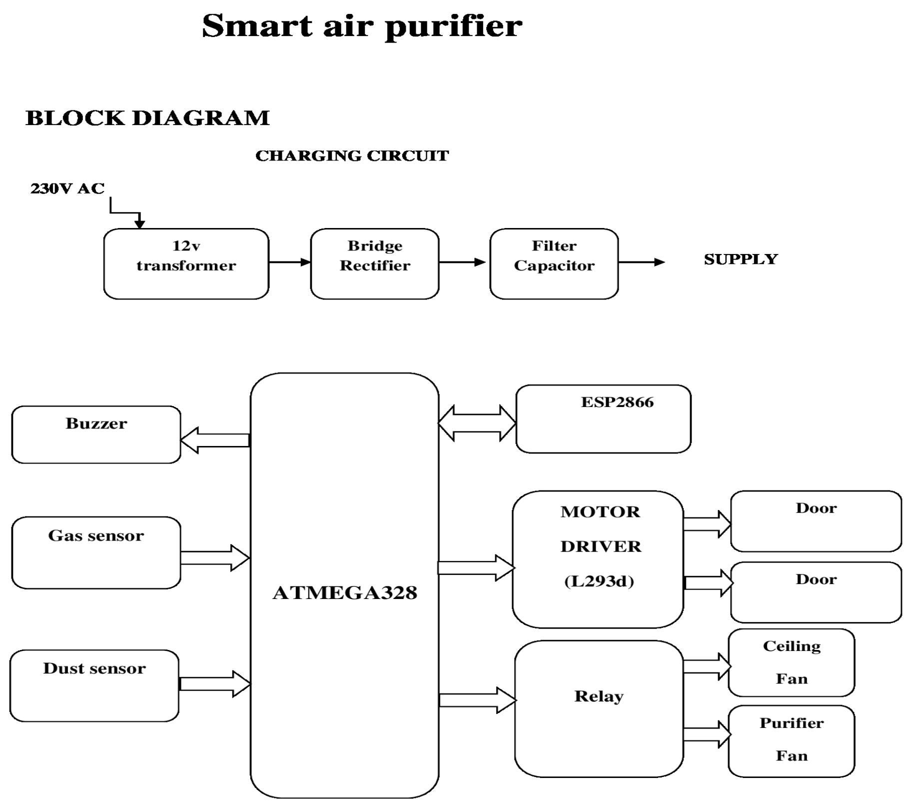

Figure 4.1: Main Block Diagram

sensor values, the relay is also energised in order to control both the ceiling fan and the purifier fan. All information regarding the sensor values and status of the purifier is shared to a mobile browser which can be remotely operated with the help of a wifi module.

5 Detailed Design

5.1 Main Circuit Diagram

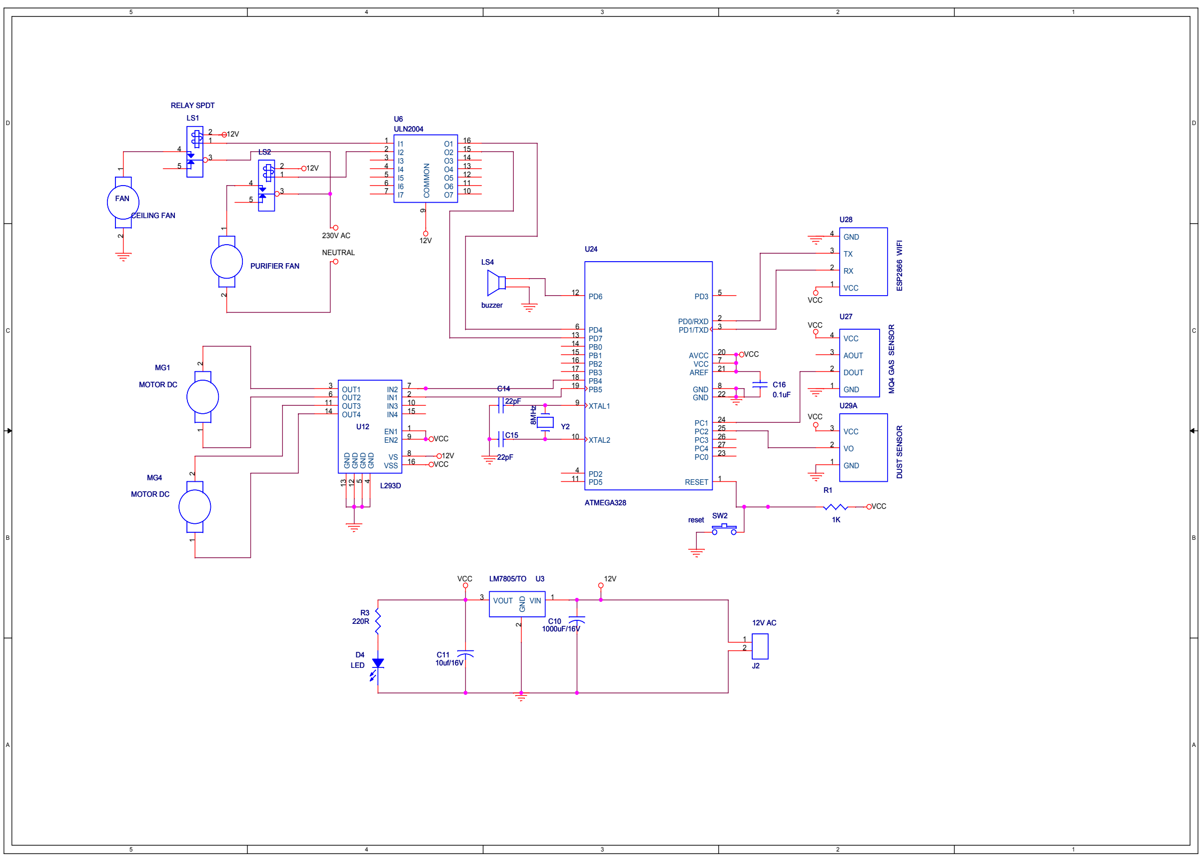

Figure 5.1: Main Circuit Diagram

Main circuit diagram shown here includes all sub systems and air purifier system as mentioned earlier in the paper. This includes the air purifier, ceiling fan control, methane sensing unit, dust sensing unit, alarm circuit, and connection to ESP8266 wifi(which allows us to connect to internet). We give a 12V DC power supply from an adapter and then rectify this using a capacitor. Next we use a voltage regulator to regulate this voltage to 5V to get Vcc and rectify the output using a capacitor. This Vcc is given to the arduino as well as all sensors for their operation.

5.2 Architecture and Structural Design

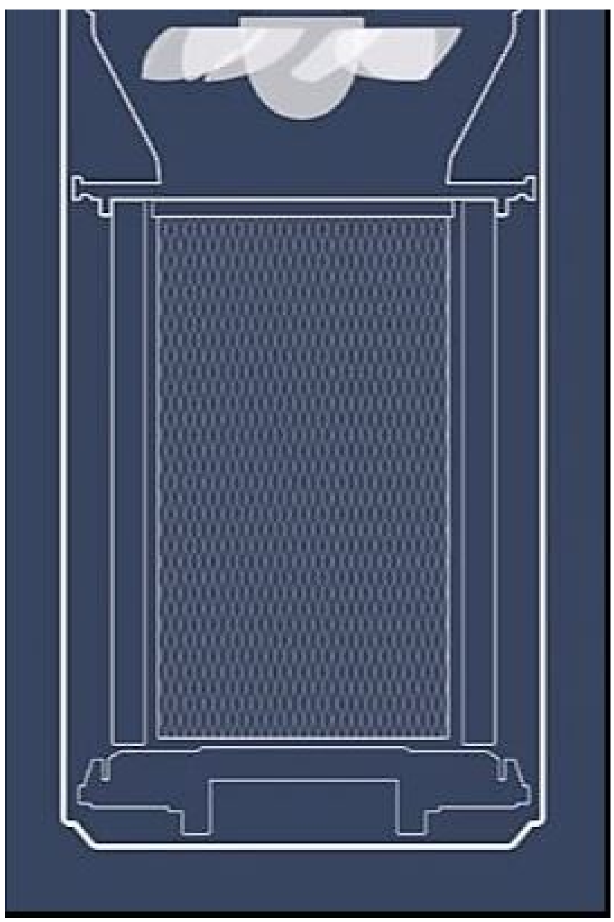

Figure 5.2: Basic Architecture

Fig 5.2 represents the cross sectional view of the air purification system. The casing has an box shape with round edges and the layers of filters are enclosed in a cylindrical shape. Turbine and exhaust fan of the system are located at the top most part. Air is taken in from the lateral section of the air purifier through number of pores.

Plywood and perforated aluminium sheets are the materials selected for making the casing. Plywood is selected because it is easy to work with. Along with that it is also cheap and easily available. Aluminium is also selected because of similar reasoning. The plywood is cut into 4 pieces and each sheet is drilled in the exact design for a 360 degree air intake .The holes drilled are covered with perforated sheets to provide primary filtration. Primary filters remove all hair sized particles including animal fur,large particles that can easily clog the filter .Silica gel is applied on the edges of the casing for maximum insulation and this results in best performance of the air purifier to reduce energy consumption. Since the air filter has more surface area(360 degrees) it last longer and filters more efficiently.

5.3 Filtration System Selection

Regardless of the type of filtration principle there are a number of basic requirements that need to be fulfilled. Any filtration system must:

- Provide sufficiently high filtration efficiency over the entire service life.
- Have low air flow resistance, and preferably a small increase of the pressure drop over time.
- Prevent the release of harmful or annoying substances into the airflow being cleaned.

Now lets compare the available filtration technologies,

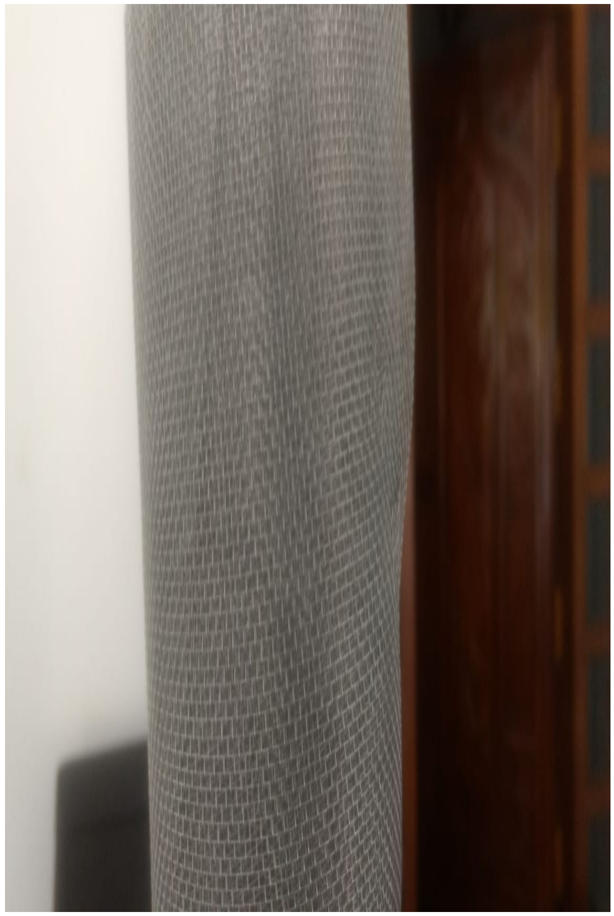

Figure 5.3: Perforated aluminium sheet

- Filtration by means of mechanical filters: This is probably the most common and the most mature technology. This air cleaning method mainly involves mechanical collection of particles on porous or fibrous media. The mechanisms of removal are diffusion, interception, inertial deposition and the sieve mechanism. Higher filtration efficiency implies a higher pressure drop and consequently higher energy consumption for fans. HEPA filters coupled with fans are most common type of filter technology used for high efficiency purification.

- Filtration of Gaseous materials: Gas-phase air filters remove gases and odours by using a adsorbent, to adsorb the pollutants. Activated carbon is the most

Figure 5.4: Plywood

common adsorbent. Alternatives are activated aluminum, silica gel, zeolites, organic synthetics etc. A variety of gases and vapours are adsorbed onto surfaces and into pores of solid media, with or without chemical reaction. A variety of VOCs can be adsorbed but the process is typically not efficient for low molecular weight constituents and permanent gases. However, reactive gases, e.g. nitrogen dioxide, may be captured with high efficiency if the adsorption filter has been impregnated with a suitable substance. Thus, gas-phase filters are typically specific to one or a limited number of gaseous pollutants; they will not reduce concentrations of pollutants for which they are not designed.

- Electrostatic precipitation: Electrostatic precipitators (ESPs) are the most common type of electric air cleaners based on electrostatic attraction to trap charged particles. Air is drawn through an ionization section where particles obtain an electrical charge. They employ a one-stage or two-stage design for particle collection. In the less expensive but also less effective single-stage design, a charged medium acts to both charge and collect airborne particles. A two-stage design employs a high voltage electrode or wire, which places a charge on the incoming airborne particles. In the second stage the charged particles are drawn between a series of oppositely charged metal plates, which attract the charged particles from the air causing them to precipitate onto the metal plates. Charged particles passing through the collection section of the equipment, and consequently supplied to the indoor air, are sometimes deemed as a potential health risk.

- Bipolar air ionization: Ion generators or ionizers disperse charged ions into the air, i.e. produce local clusters of positive, negative or bipolar () ions. Clustered ions then electrically charge airborne particles so that they attach to nearby surfaces such as walls or furniture, attach to one another and settle faster. Furthermore, the removal by filtration may be facilitated if the particles are charged. Cluster ions are sometimes claimed to also chemically react with and destroy VOCs. Air ionizers are distinct from both electrostatic precipitators and ozone generators. In air ionization, PMx is electrically charged through direct contact with bipolar air ions. However, there is a risk of ozone generation both from electrostatic precipitators and air ionizers. In a recent extensive literature review of air ionization devices it has been noted that no firm conclusions can be drawn about positive or negative effects of air ionizers on sick building syndrome symptoms. Ozone generation by these devices is an issue although generation rates are considerably lower than from dedicated ozone generators.

Several studies found that even weak ozone generating air ionizers are capable of maintaining steady-state levels of ozone in small rooms with nonreactive surfaces that are well in excess of the health-protective standards.

- Ozone generation: Ozone generators use UV light or electrical discharge to intentionally produce ozone. Ozone (referred to as trivalent oxygen or saturated oxygen by some manufacturers) has been used in water purification since 1893. Introducing ozone into the air stream can have beneficial effects under controlled conditions were humans are not exposed. However, ozone is of concern when considering spaces for human occupancy. All reviewed literature does not recommend use of ozone generators as air cleaning device. One further health risk from ozone generators is the potential for formation of ultrafine particles when these devices are operated in the presence of terpenes, which has also been pointed out by a study. Similar conclusions about formation of fine and ultrafine particles in presence of common unsaturated VOCs have been drawn in another study.

5.3.1 Conclusion

The mechanical fiber filter technology is well established and standardized and works well for particulate matter. The replacement frequency is of crucial importance since impaired perceived air quality and excessively high pressure drops will be the result if the filters are not replaced regularly.

Gas-phase air filters are very effective for removal of a variety of gases, vapours and odours if appropriate types and amounts of sorbents are used. This may impose quite a high pressure drop. Again, the filter replacement interval is of major importance. There is generally no possibility to get any indication about when the adsorption filter has become saturated and should be replaced.

Electrostatic precipitators can be very effective for particle removal at pressure drops much lower compared to fiber filters. However, the risk of ozone generation is a serious disadvantage.

Air ionization is an inconclusive technology regarding indoor air quality. As with electrostatic precipitators ozone generation is a serious issue.

Ozone generators produce excessively high concentrations of ozone. Valid objections have been raised to this technique based on ozone toxicity and secondary reactions of ozone with specific types of indoor pollutants. Thus, ozone generators are not of interest for cleaning in environments for human occupancy.

So we can finally conclude that the best option is to combine two filtration technologies namely the HEPA filter and the activated carbon filter for effective purification of particulate matter and gaseous material.

5.4 Filtration System

Our air purification system incorporates a 3 layer filtration system. It consists of a prefilter, HEPA filter and an activated carbon filter. Pre-filters captures large debris such as hair fur, dust and pollen. Once these particles are trapped, the other filters inside the air purifier can work at maximum levels. It prolongs the life of inner layer of filters. High Efficiency Particulate Air filters (HEPA filters) are made out of very fine glass threads with a diameter of less than 1 micron (a micron is 0.00004 in, 0.001 mm). They act as the main filtration layer. Activated carbon is a porous material that can absorb volatile chemicals on a molecular basis, but does not remove larger particles. It is normally used in conjunction with other filter technology, especially with HEPA.

5.4.1 Pre Filter

HEPA filters meant to capture small particles like 0.25 micrometer to 0.3 micrometer Even though HEPA filters have a large number of pleats which gives them lots of surface area, they can fill up more quickly if the larger particles are not pre-filtered out. In a typical family, with kids, dogs or cats, and a lifestyle that is highly active, an air purifier has to deal with a lot of large particles. By having pre filter will reduce the burden on the HEPA filter or carbon filter. Pre filters improve the lifetime or longevity of HEPA filter. Different types of pre filters available in market and can be classified based on two aspects washability and packaging. Washable pre filters are little costlier around Rs.700 but you can wash them and reuse them multiple number of times. Non washable pre filters are not washable, cheaper around Rs.150 to Rs.300. You cannot wash them. They are use and throw model. But you need to replace them at regular interval of time like 3 months. Pre filter combined with HEPA filter and Activated carbon is a type of pre filter that is clubbed with HEPA filter so that you need to replace the whole filter. You cannot just replace only the pre filter as they are combined with HEPA so it means that pre filter is not washable as well. We have selected pre filter combined with HEPA filter and activated carbon filter. The main advantages of this type of pre filter are there are no separate monitoring required for each filter stage (pre filter, HEPA filter, activated carbon filter),ease of access,there is no layer by layer replacement of filter required,it has good availability in market. The material used for the pre filter is aluminium perforated sheet. This is because aluminium is strong, durable and easily available.

5.4.2 HEPA Filter

HEPA or high emission particulate air filters are the commonly used main filters in air purification systems. HEPA filters are made out of very fine glass threads with a diameter of less than 1 micron (a micron is 0.00004 in, 0.001 mm). By comparison, a human hair has a diameter of about 75 microns (0.003 in, 0.07 mm). The fine glass threads are tangled together and compressed to form a filter mat. Because the individual threads are so microscopic, most of the mat consists of air. The openings in the mat are very small, generally less than 0.5 micron (0.00002 in, 0.0005 mm). HEPA filters will collect particles down to 0.3 microns (0.00001 in, 0.0003 mm) in diameter. Even though the filter may only be 0.10 in (2.5 mm) wide, it would consist of 2,500 layers of glass threads.

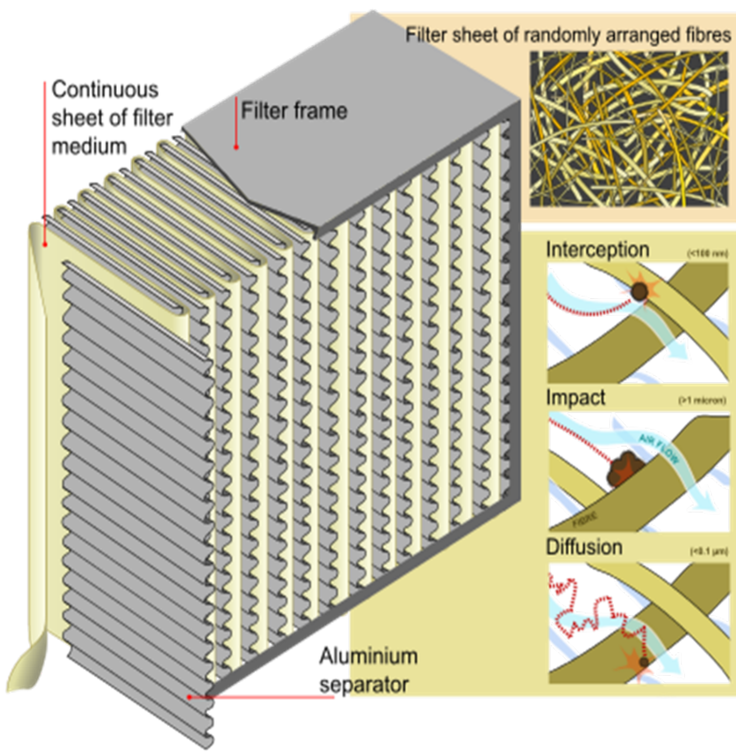

Figure 5.5: HEPA Filter

5.4.3 Activated Carbon Filter

HEPA filters cannot remove volatile organic compounds from the air, therefore it can do nothing to reduce odours. For this reason, most air purifiers are equipped with a pre- or post-filter composed of activated carbon. Activated carbon is produced by heating a carbon source (coconut shells, old tires, bones, etc.) at very high temperatures in the absence of oxygen, a process also known as pyrolysis or destructive distillation. The activation process forms millions of cracks in the carbon grains. These cracks have diameters of about 0.002 microns (0.000002 mm). Because there are so many cracks, the activation process provides the carbon with an enormous surface area per weight about 6.5 acres per oz (1,000 square meters per gram). The millions of cracks provide locations where organic compounds can be adsorbed. In addition, the surface of the carbon carries a residual electrical charge that attracts non-polar chemicals (chemicals that do not have separated positive and negative charges) to it. Activated carbon is very effective at adsorbing odour producing compounds. It can be used as the third layer of the filtration system of the air purifier.

Figure 5.6: Three Layer Filter Design

5.5 ESP8266

Minimum of 7 external components can be connected. It integrates a microprocessor and a wifi module to provide internet connectivity. It has a wide temperature range of -40C to +125C. The ESP8266 micro controller integrates a Tensilica L106 32-bit RISC processor, which achieves extra-low power consumption and reaches a maximum clock speed of 160 MHz It has high durability and is capable of functioning consistently in industrial environments, due to its wide operating temperature range.

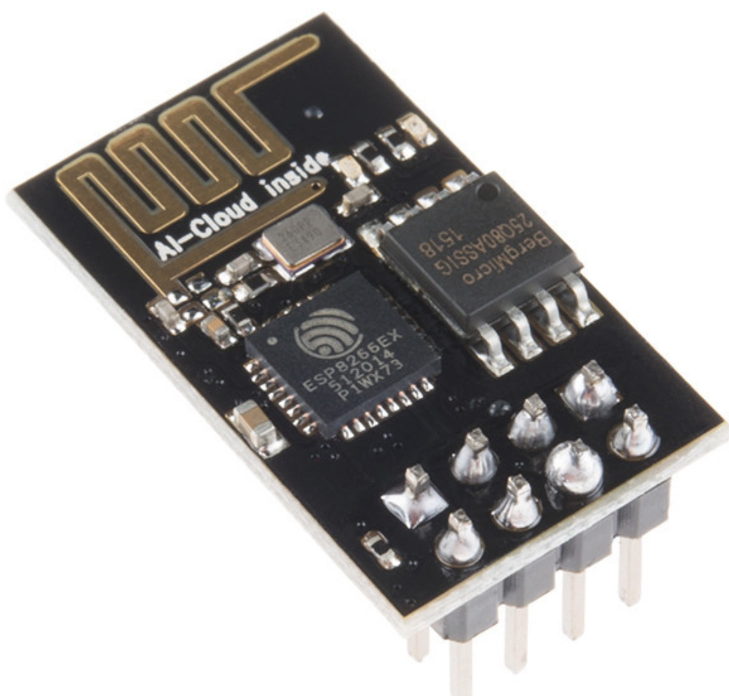

Figure 5.7: ESP8266

5.6 Dust Sensor

Optical dust sensor is used for detection of dust particles in the air purifier system. Two main optical sensors under consideration are gp2y1010au0f and SM-PWM-01C.Both of these sensors use IR rays that reflect over the surface of dust particles and return back to the detector. We have opted to use gp2y1010au0f sensor as only this among the two has quantitative measurement of dust particles and this is important for the working of our product. This sensor produces output voltage in the form of pulses which is proportional to the density of dust present. Hence, quantitative measurement is possible. The output voltage of the sensor consists of two components: small voltage due to stray light inside the sensor and voltage proportional to density of dust present. The main features of Gp2y1010au0f are Compact and thin package(46 x 30 x 17.6 mm), With the application of pulse output system, the device can detect even single house dust, house dust and cigarette smoke can be distinguished.

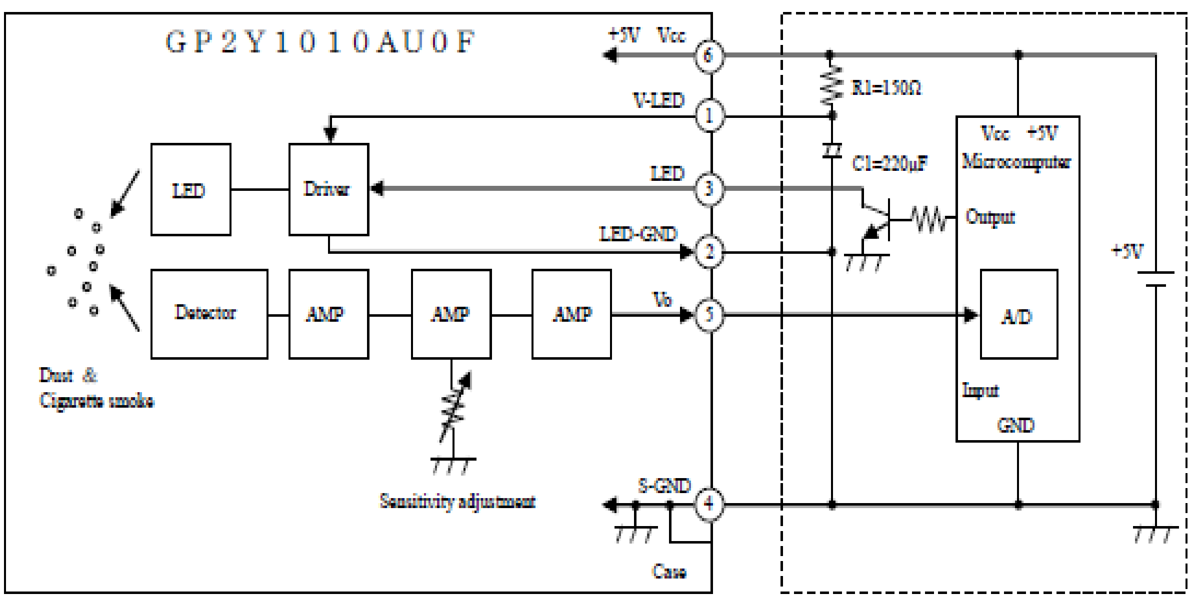

Figure 5.8: Dust Sensor Circuit

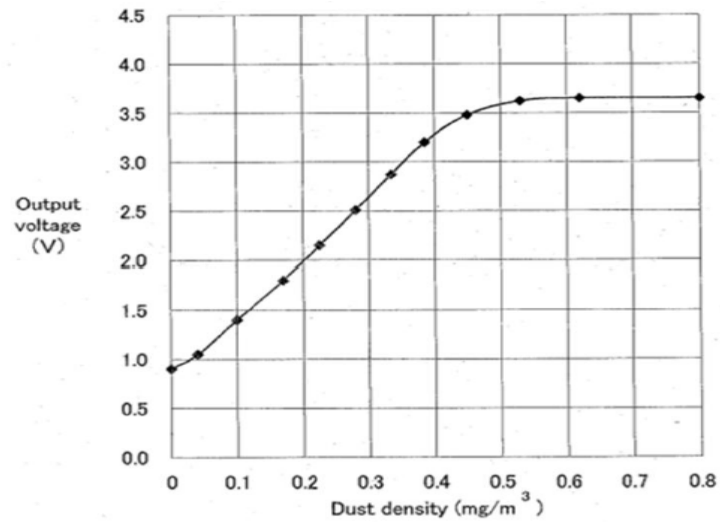

Figure 5.9: Dust Sensor Characteristics

5.6.1 Obtaining dust density from the dust sensor

From fig 5.10 we can see there is a function called analogRead() used in the code. As we know dust sensor senses the dust and assigns voltage corresponding to it. analogRead() functions assigns an analog value from 0 to 1023 according to the measurement. An intermediate variable calcVoltage is assigned. The final expression calculates the dust density in ppm. 0.17 is the constant specified by dust sensor manufacturer and 0.1 is a threshold value.

```
voMeasured = analogRead(Dust_Sensor);

delayMicroseconds(deltaTime);

digitalWrite(Dust_Sensor_ledPower,HIGH);

delayMicroseconds(sleepTime);


calcVoltage = voMeasured*(5.0/1024);

dustDensity = 0.17*calcVoltage-0.1;
```

Figure 5.10: Dust Sensor Characteristics

5.7 Window Automation

We are considering windows to be of sliding type. Automation of the window is achieved by using IoT. We have selected the linear actuator for the mechanical movement because of its ease in linear movement and availability in our application scenario. The other methods that we have studied are:

5.7.1 Rack And Pinion Mechanism

The first idea of a mechanism to open and close a window was a simple rack and pinion gear assembly. The window will sit on the rack of the assembly where the pinion gear, connected to an electrical motor, moves the rack with the pane causing it to open or close. This idea was rejected for many reasons. This assembly is noisy and causes discomfort to the residents of the room. Another reason we rejected this mechanism is that it uses a lot of power to operate. And a third reason is that it would be unappealing from an architectural point of view.

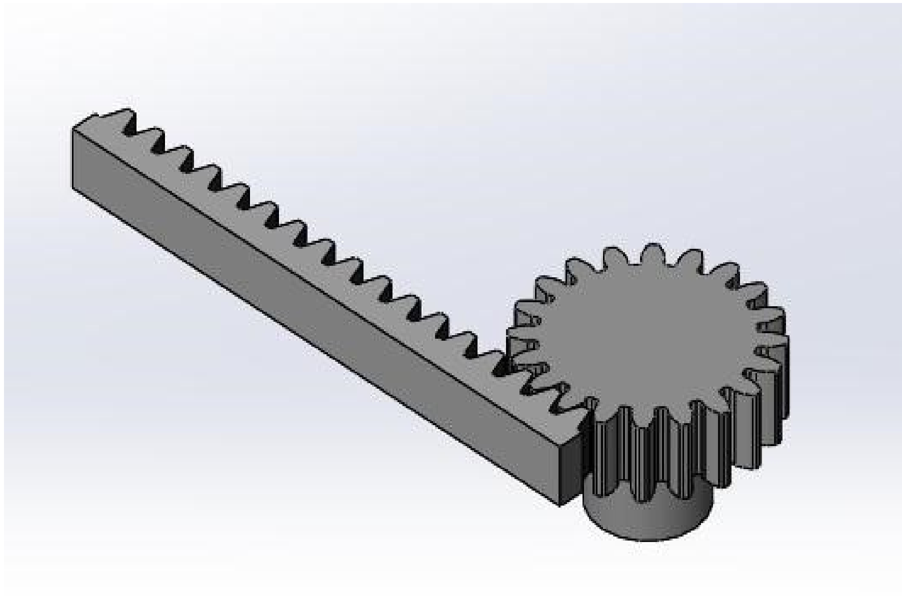

Figure 5.11: Rack And Pinion System

5.7.2 Rope And Pulley Mechanism

Our second option was to use the simple rope and pulley design operated with a motor. This was also rejected because the amount of force needed to operate this kind of assembly was very high and the fact that this assembly would be very expensive.

Figure 5.12: Rope And Pulley System

5.7.3 Linear Actuator

It is very compact in size, very easy to install and operate. It also can be hidden so it will have zero effect on the aesthetics of the room. But the cost of a linear actuator is substantially high. Because of this, our purifier may become economically infeasible. So we opt to use two CD drives to obtain the required functions. A CD drive resembles a linear actuator in its functionality and because of its low cost, we select two CD drives for window automation. Two Cd drives are used for extra power.

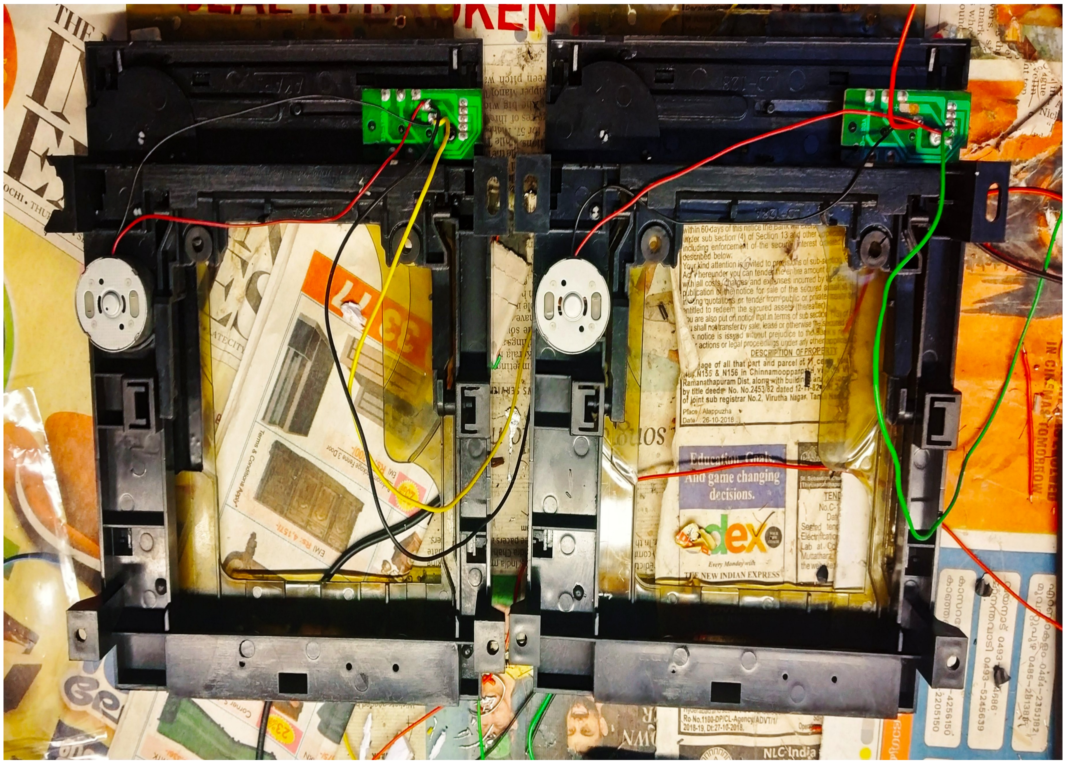

Figure 5.13: CD drive system

5.8 Exhaust Fan

Exhaust fan selected for our project is 150mm (sweep), 25W power output fan capable of 275 cubic meters of air delivery. Single phase AC motor is used as the driving motor. It works on 220 to 240 volts, 50 Hz AC supply, 1300 rpm.

Figure 5.14: Exhaust fan top view

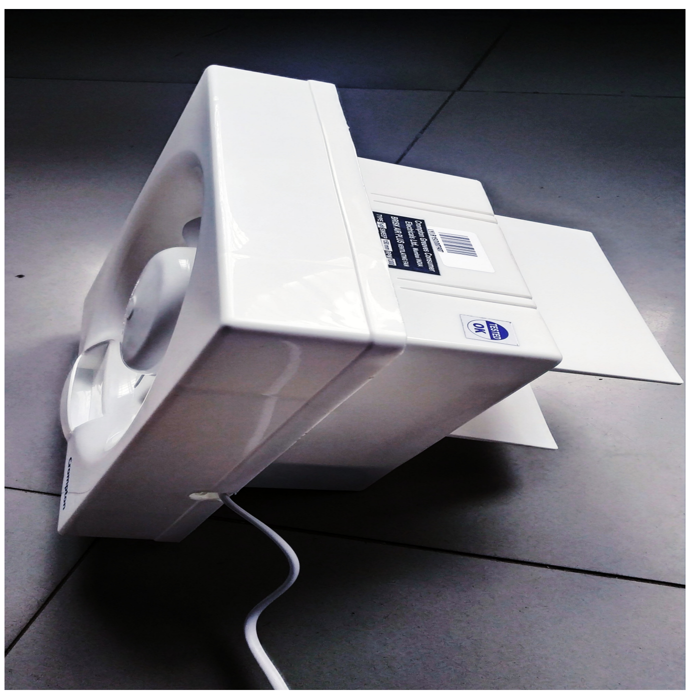

Figure 5.15: Exhaust fan side view

5.9 Methane Sensing System

We use MQ4 sensor to sense methane in the air. This sensor output is given to the arduino for processing. Based on the output from the arduino, the buzzer produces an alarming sound. When the methane sensor gives a high output buzzer produces an alarm sound also window opens, in window automation part.

Figure 5.16: MQ4 Gas Sensor

5.10 IoT

IoT is the internet of things. We have designed our purifier such that it suits for a smart home. The features of a smart home are that all appliances(fans, lights etc) are connected to a central controller using wires. Information from these appliances are transferred to the central controller from which they are transmitted to a web browser using a wifi module. We have also adopted the same mechanism in which the fan as well as the window we are trying to control are connected to the arduino board (which is our controller) via wires. The status of the sensors as well as the purifier is transmitted to a web browser using a wifi module. Each wifi module has a unique IP address that can e accessed with the help of a browser. Hence, we can see the status of the sensor and the purifier remotely from anywhere. This wifi module has the IP address of 192.168.4.1. Controlling of on/off functions of the purifier can also be done through the browser. Given below are simple steps to connect a mobile phone the node MCU.

step 1: Switch ON the air purifier and connect the mobile phone to node MCU wifi.

step 2: Type http://192.168.4.1 in the mobile browser. After this a web page showing air purifier stats like dust content, methane status, window status and ceiling fan status appears.

step 3: By typing http://192.168.4.1/ON in the mobile browser, we can switch ON the system and vice versa for typing http://192.168.4.1/OFF. So master control is obtained.

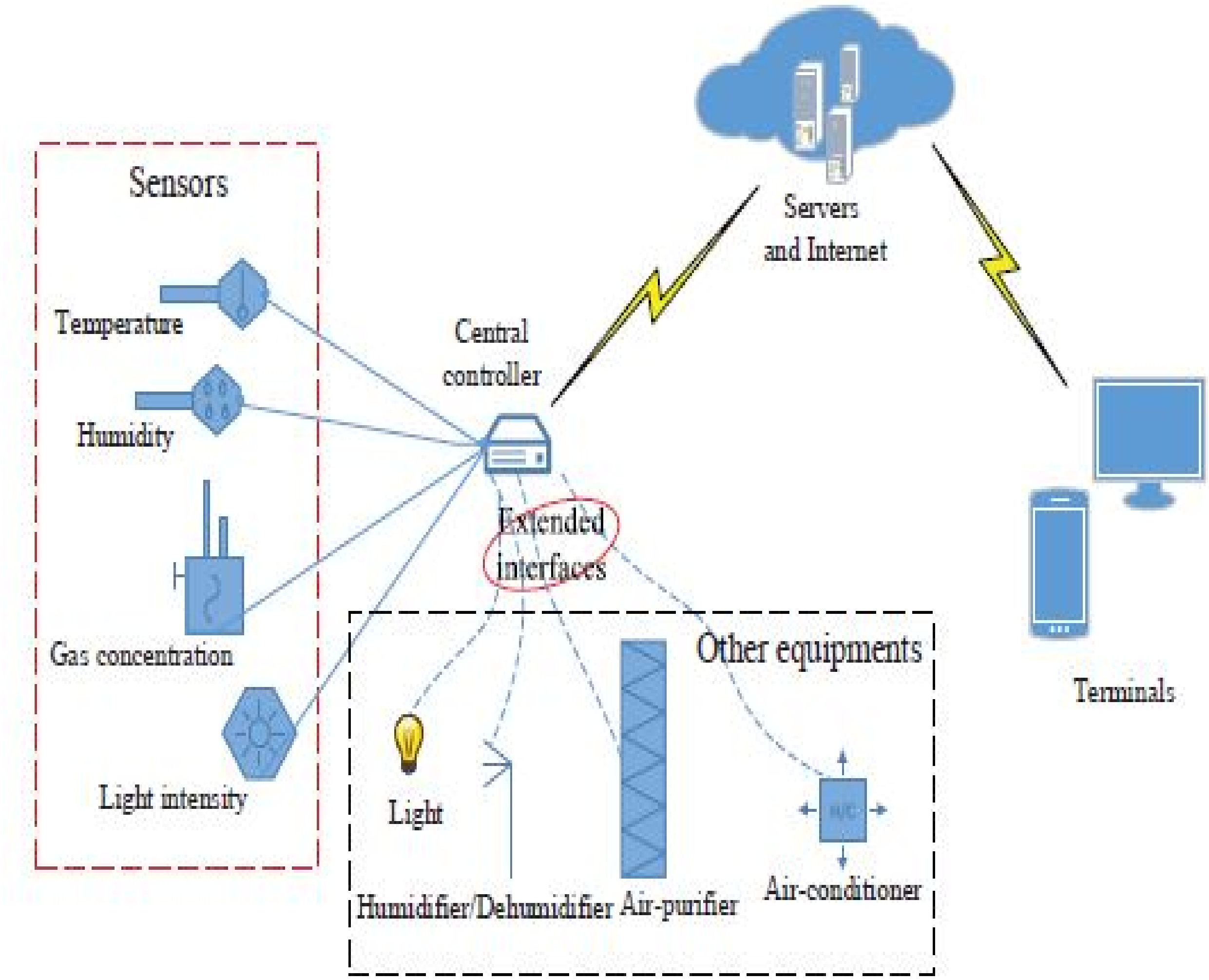

Figure 5.17: Design Diagram Of Air Purifier With Extended Interfaces

5.11 GUI

An android app made with MIT app inventor is also used. This app is specifically designed for ESP8266. The app displays all the basic information mentioned in the earlier section and also acts as the master switch for the air purification system. App is easily downloadable as zip file using any browser. It starts functioning after installation in users mobile phone.

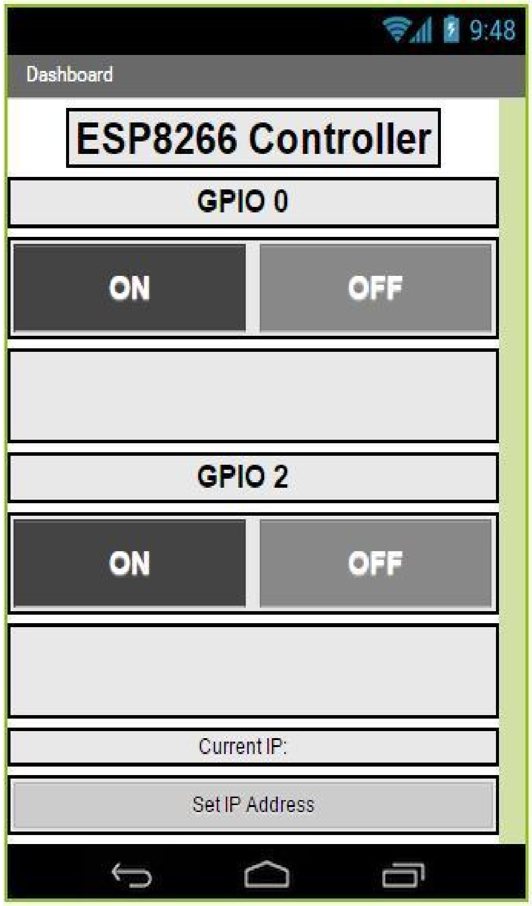

Figure 5.18: Basic layout of the app designed

5.12 PCB design

This is the PCB layout for the motor driving IC L293D. This the only PCB design in the entire project and is used in window automation.

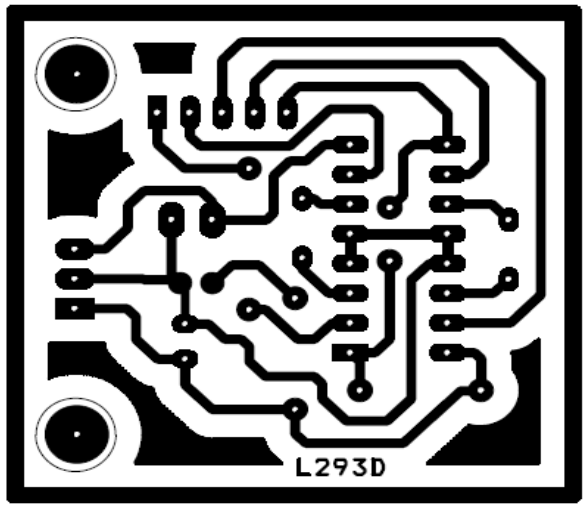

Figure 5.19: PCB design of motor driver

5.13 Arduino programming

There are only 2 arduino programs used in the project. First program dictates the purification process and the functioning of the extended interfaces (ceiling fan, window automation and methane sensing unit). The second program establishes the connection between the purification system and the internet.

5.13.1 Program for Purification process

This program consists of all the set of instructions that the air purification system has to follow. This includes the functioning of the air purifier, window automation system, methane sensing system and ceiling fan control system.

5.13.2 Program for NODE MCU

This program accomplishes the task of connecting the air purification system with the external interface (mobile phone) via the wifi module.

```
#define M11 8

#define M12 9

#define Relay_Purifier 10

#define Relay_Ceiling_Fan 13

#define gas_sensor  A0

#define Dust_Sensor  A5

#define Switch_Wifi  A1

#define buzzer    7

int Dust_Sensor_ledPower = 12;

unsigned long int Delay_Purifier_Timeout_Millis =0;

boolean Stat_Switch=0;

unsigned int samplingTime = 280;

unsigned int deltaTime = 40;

unsigned int sleepTime = 9680;

float voMeasured  = 0;

float calcVoltage = 0;

float dustDensity = 0;

int sensorValue = 0;

boolean Stat_Relay_Purifier =0, New_Stat_Close=0, Stat_Close=1,
Stat_Relay_Ceiling_Fan=0, Stat_Switch_Wifi=0;

boolean Methane_Limit=0, Dust_Limit=0;

void setup(void) {
 pinMode(M11,OUTPUT);
pinMode(M12,OUTPUT);

pinMode(Relay_Purifier,OUTPUT);

pinMode(Relay_Ceiling_Fan,OUTPUT);

pinMode(buzzer,OUTPUT);
```

Figure 5.20: Purification program part 1

```
pinMode(Dust_Sensor_ledPower,OUTPUT);

Serial.begin(9600);
}

void Window_Open(void){
digitalWrite(M11,HIGH);

digitalWrite(M12,LOW);

delay(1200);

digitalWrite(M11,LOW);
}

void Window_Close(void){
 digitalWrite(M11,LOW);

digitalWrite(M12,HIGH);

delay(1200);

digitalWrite(M11,LOW);
}

void loop() {
 digitalWrite(Dust_Sensor_ledPower,LOW);

delayMicroseconds(samplingTime);

 voMeasured = analogRead(Dust_Sensor);

 delayMicroseconds(deltaTime);

 digitalWrite(Dust_Sensor_ledPower,HIGH);

 delayMicroseconds(sleepTime);

 calcVoltage = voMeasured*(5.0/1024);

 dustDensity = 0.17*calcVoltage-0.1;

 if ( dustDensity < 0)
{
 dustDensity = 0.00;
}

if( analogRead(Switch_Wifi) > 100 )

 Stat_Switch = 1;

else
   Stat_Switch = 0;

if(dustDensity > 0.5)
```

Figure 5.21: Purification program part 2

```
{
 Dust_Limit=1;
}

else {
  Dust_Limit=0;
 }


int Methane_Value = analogRead(gas_sensor);


if(Methane_Value > 500)
{
 Methane_Limit=1;
}

else {
 Methane_Limit=0;
}



if( Methane_Limit && Dust_Limit )
{
Stat_Relay_Purifier =1;

 Stat_Relay_Ceiling_Fan =1;
 New_Stat_Close=0;
 Delay_Purifier_Timeout_Millis=millis();
    }

else if( Methane_Limit )
{
  Stat_Relay_Purifier =1;

   Stat_Relay_Ceiling_Fan =1;

New_Stat_Close=0;

   Delay_Purifier_Timeout_Millis=millis();
    }

else if( Dust_Limit )
{
  Stat_Relay_Purifier =1;

   Stat_Relay_Ceiling_Fan =1;
   New_Stat_Close=1;

   Delay_Purifier_Timeout_Millis=millis();
    }

else {
 if( ( millis() - Delay_Purifier_Timeout_Millis) > 30000  )
{
  Stat_Relay_Purifier =0;

   Stat_Relay_Ceiling_Fan =0;

   New_Stat_Close=1;
        }
    }
```

Figure 5.22: Purification program part 3

```
 if(!Stat_Switch )
{
  New_Stat_Close=1;

   Stat_Relay_Purifier =0;

   Stat_Relay_Ceiling_Fan =0;
    }


if(New_Stat_Close != Stat_Close )
{
  if(!Stat_Close) {

   Serial.println("Clossing Windows");

   Window_Close();

   Stat_Close=1;
        }

   else {
 Serial.println("Opening Windows");

   Window_Open();

   Stat_Close=0;
        }
    }


  if( Stat_Relay_Purifier )
  {
 Serial.print("Purifier : ON ");

    digitalWrite(Relay_Purifier,HIGH);
    }

else {
 Serial.print("Purifier : OFF ");

    digitalWrite(Relay_Purifier,LOW);
    }


if( Stat_Relay_Ceiling_Fan )
{
   digitalWrite(Relay_Ceiling_Fan,HIGH);

    Serial.print("\tFAN : ON ");
    }

else {
 Serial.print("\tFAN : OFF ");

    digitalWrite(Relay_Ceiling_Fan,LOW);
    }


    Serial.print("Dust: ");

    Serial.print(dustDensity);
```

Figure 5.23: Purification program part 4

```
    Serial.print("PPM");


    Serial.print("\t Methane = ");

if(Methane_Value > 500)
    {

    Serial.print("HIGH");

    digitalWrite(buzzer,HIGH);
    }

else {
 Serial.print("LOW");

    digitalWrite(buzzer,LOW);
    }


    Serial.print("\t Status: ");

if( Stat_Switch )
    {
  Serial.println("Enabled"); }

else {
  Serial.println("Disabled"); }


    delay(1000);
}
```

Figure 5.24: Purification program part 5

```
#include <ESP8266WiFi.h>


const int short StatusLEDPin=13;

const int short ControllingPin=4;

WiFiServer server(80);
 //Initialize the server on Port 80

String inputString = "";
 // a string to hold incoming data
String inputString_backup = "";
 // a string to hold incoming data
boolean stringComplete = false;
 // whether the string is complete

boolean Purifier_Cut_Flag=0;



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

 pinMode (StatusLEDPin ,OUTPUT);

 pinMode (ControllingPin ,OUTPUT);

 digitalWrite (StatusLEDPin,LOW);

 digitalWrite (ControllingPin,LOW);


 WiFi.mode(WIFI_AP);
//Our ESP8266-12E is an AccessPoint
  WiFi.softAP("Air_Purifier", "12345678");
// Provide the (SSID, password);

server.begin();
// Start the HTTP Server


//Looking under the hood
Serial.begin(9600);
//Start communication between the ESP8266-12E and the monitor window
IPAddress HTTPS_ServerIP= WiFi.softAPIP();
// Obtain the IP of the Server
Serial.print("Server IP is: ");
// Print the IP to the monitor window
Serial.println(HTTPS_ServerIP);

 digitalWrite(ControllingPin, HIGH);

}


void StatusLEDBlink (int LedDelay)
{
  digitalWrite (StatusLEDPin,HIGH);

 delay (LedDelay);
```

Figure 5.25: NODE MCU program part 1

```
 digitalWrite (StatusLEDPin,LOW);

 delay (LedDelay);
}


void serialEvent()
{
  while (Serial.available())
{
    // get the new byte:
    char inChar = (char)Serial.read();

  // add it to the inputString:
    inputString += inChar;

 // if the incoming character is a newline, set a flag

  // so the main loop can do something about it:
    if (inChar == '\n')
{
      stringComplete = true;
    }
  }
}


void loop() {
    serialEvent();

   if (stringComplete)
{
 inputString_backup=inputString;

     inputString = "";

    stringComplete = false;
    }


 // put your main code here, to run repeatedly:
    StatusLEDBlink (250);

   WiFiClient client = server.available();

  if (!client) {
        return;
    }


  client.print(inputString_backup  );



 //Looking under the hood

  Serial.println("Somebody has connected :)");

 StatusLEDBlink (1000);

  //Read what the browser has sent into a String class and print the request to
the monitor
```

Figure 5.26: NODE MCU program part 2

```
 String request = client.readStringUntil('\r');

  //Looking under the hood

  Serial.println(request);

  if (request.indexOf("/ON") != -1)
  {
Serial.println("On  Command Rxd");

   digitalWrite(ControllingPin, HIGH);
}

  else if (request.indexOf("/OFF") != -1)
 {
Serial.println("Off  Command Rxd");

 digitalWrite(ControllingPin, LOW);
     }
}
```

Figure 5.27: NODE MCU program part 3

5.14 Program conditions

In the earlier section we saw the programs which controls the purification process. This section explains different conditions and scenarios in these programs.

We can divide all the encounters of the air purification system into 5 different scenarios

scenario 1: The control override through the mobile app. Control through the mobile app has the highest priority. If the air purification system is shutdown using the mobile app, it is completely shutdown irrelevant of the environment. After mobile shutdown the air purifier can only be switched ON by the mobile app.

scenario 2: Presence of both methane and dust in air. In this state methane has a higher priority than dust. As a result user is notified through the mobile app and an alarm which sets of in presence of methane. Windows are opened ,ceiling fan and air purifier is switched ON.

scenario 3: Presence of methane only. In this condition measures mentioned in the above scenario is repeated.

scenario 4: Presence of dust only. In this condition, air purifier and ceiling fan is switched ON. Also window is closed. User is notified and amount of dust is also specified.

scenario 5: Without the presence of dust and methane. This is the default condition. In this state air purifier and ceiling fan is in OFF state. Windows remain closed. Room will be continuously monitored for dust and methane presence.

6 Cost Analysis

A detailed cost analysis covering all components and sections of our product is done. By summing up all the costs, we can find out the total cost incurred by us during the manufacture of our purifier. The total cost sums up to Rs.7223. This is a very economical product as normal purifiers cost around Rs.9000. These products are produced in bulk and does not offer as much features as our purifier. Our purifier provides automation features which are a new innovation. These features are incorporated in our product at low costs compared to other products. Bulk production of our product can result in further decrease of the overall incurred cost. Thus, the proposed design is feasible and can easily be implemented in an industrial scale so as to produce an air purifier that is economically feasible and has a lot of features.

Sl. No	Item	Quantity	Cost (in Rs)
1.	Arduino	1	450
2.	16 MHz Crystal oscillator	1	40
3.	Filter system	1	2000
4.	ESP8266	3	600
5.	Casing	1	1000
6.	Dust sensor	1	440
7.	Methane sensor	1	200
8.	Buzzer	1	25
9.	L293D	1	60
10.	Purifier fan	1	1130
11.	Relay	2	10
12.	ULN2004	1	20
13.	LM7805	1	13
14.	1K Resistor	1	3
15.	0.1 microfarad capacitor	1	5
16.	22 picofarad capacitor	2	4
17.	1000 microfarad capacitor	1	3
18.	10 microfarad capacitor	1	2
19.	220 ohm resistor	1	4
	Total		7223

Table 6.1: Cost Study

7 Engineering Documentation

7.1 Component Specifications

1. Dust Sensor Model: GP2Y1010AU0F, Operating voltage: 5V, Max current: 20mA, Operating Temperature: 10 - 650C.

2. Methane Sensor Model: MQ-4, Operating Voltage: 5V, Operating Temperature: -10 - 500C.

3. Wi-Fi Module Model: ESP8266, Memory: 32KiB instructions, 80KiB user data.

4. Exhaust Fan Model: Electric fan (ventilating type), Power output: 25W, Voltage rating:220/240V, 50Hz AC Speed: 1300 rpm.

5. Motor Drive for linear actuator Model: L293D, Voltage rating: 5V, Current rating:0-36 mA, Maximum Power: 25W, Weight: 26g.

6. ULN2004: output voltage: 50V, output current per driver: 500mA

7. ATmega 328: 32K flash program memory, 2K internal SRAM

7.2 User Interface

User interface used in this system is a Mobile browser interface. All real time data from the sensors and operation status of the air purification system is sent over Wifi and can be accessed by the user through a web browser. Each wifi module has a specific ip address through which the information can be accessed. All information from the sensors are sent via wifi by the wifi module. This information can be accessed by the user by tying in the ip address in a web browser. Control of the air purifier can also be done using the same. The main set of features accessible through the web browser are device ON/OFF, dust/pollutant concentration within the room and presence of methane. Statuses of both ceiling fan and window is also provided. A mobile app is also provided which performs the basic functions mentioned above.

8 Implementation

8.1 Interfacing of sensors with arduino

In this stage, we connected all sensors to the arduino and programmed the arduino. All values from the sensors were read on the arduino.

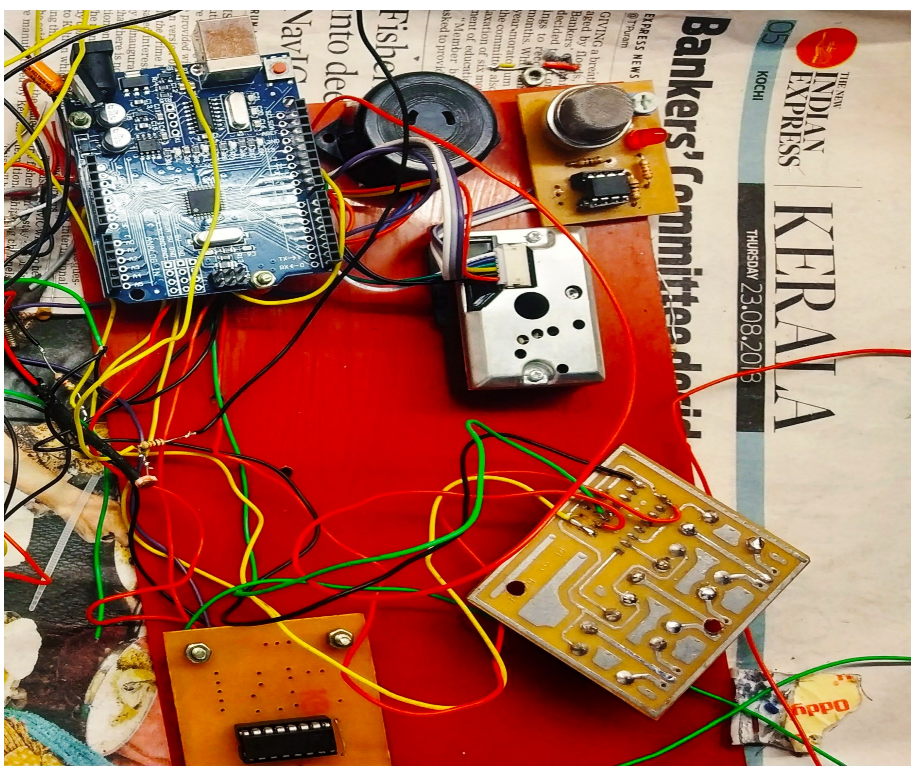

Figure 8.1: Interfacing of sensors with arduino

8.2 Window Automation

The window automation sub section consists of a prototype of a sliding window made from a sheet. This window prototype opens and closes according to the functioning of the air purifier and the presence of methane. The prototype closes automatically when the air purifier starts working and in presence of methane the prototype automatically shuts. The linear actuating mechanism implemented in CD drive is used in the prototype for window automation. A motor driver is used to connect the arduino board and motor of CD drive.

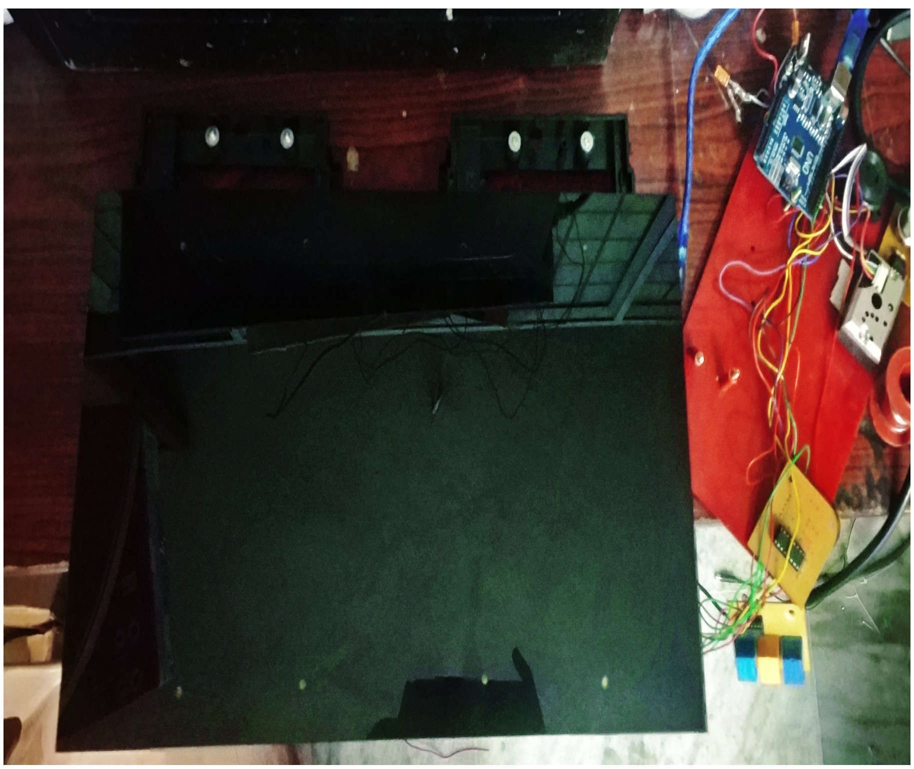

Figure 8.2: Window automation along with methane sensing unit

8.3 Methane Detection

To the arduino we used for the automation of the window we incorporate the methane sensing unit .The methane sensor gives high or low output to the arduino board, the program on the board decides to give functions based on the value of the sensor. When the value of methane sensor gives high it indicates the presence of methane in the atmosphere and hence the windows are opened and and alarm circuit is triggered.

8.4 Casing

For the casing plywood is used as the prime material. Casing resembles a cuboid shape. Four faces of the casing drilled with holes so that sufficient air flow is obtained. A wooden door is also fixed as shown in the figure. This door is used for removal of the filter. Base of the casing is lifted up so that we can easily incorporate electronic components inside the box.

Figure 8.3: Casing sideview

8.5 Mechanical components

Mechanical components consists of filter and exhaust fan. They are arranged vertically. Filter is placed such that air that is taken in passes completely through the filter and is purified. The fan is placed such that maximum air is drawn from the outside and passed through the filter.

Figure 8.4: Casing with door

Figure 8.5: Casing topview

Figure 8.6: Alignment of filter with respect to casing

8.6 Testing

We have conducted the testing. All results were as expected. The filtration process depends upon the size of the room selected. For a small room, the filtration time was about 3 hours.

9 Results & Conclusion

9.1 Main Results

The window automation is completed and testing the air purifier sensors and circuits are also completed. Ceiling fan on/off control was obtained as per requirements.

Adequate purification was obtained in a room of 200 sq.feet in 1 hour. Mathematically it was predicted that a room of 375 sq.ft could be purified in an hour. Delay in purification can be accounted to losses like lesser air flow in practical conditions.

9.2 Conclusion

IOT based smart air purifier combines the concept of smart home with air purification technology to make an efficient and modern form of air purification system. Novelty of this device is that the air purifier can intercommunicate with other devices which also regulates air flow in a room so efficient purification can be achieved. Devices like ceiling fan and ventilation system are controlled to achieve optimum efficiency.Methane leakage in household has led to numerous poisoning cases, our intelligent air purifier system detects the presence of methane, alerts the user with an alarm and adjusts the ventilation to reduce methane concentration. Low cost at which the device is offered makes it more accessible compared to existing air purifiers

Figure 9.1: IoT based smart air purification system with sensors visible

available in the market.

Figure 9.2: Topview of air purifier

Figure 9.3: IoT based smart air purification system with filter section visible

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