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Design and Implementation of IoT Supported Gas Detector System for Domestic Usage

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ABSTRACT-In this study, if any of the concentrations of CO in house, cigarette and fire smoke, CNG (methane) and natural gas odor, temperature and humidity reaches to the threshold value, we send our signal to our smart home automation systems we designed to adjust the air condition, aspirator and ventilation equipments automatically for healthy living in the home.
The Arduino Mega 2560 controller card, MQ-2, MQ-4, MQ-9, DHT11 and DS18B20 sensors were used in the study. Furthermore, the use of the Arduino card ensures that the system is open to be developed and can be upgraded according to the target of usage.
KEYWORDS-Gas Detector, Smoke detection, IoT, Arduino, open source.

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I. INTRODUCTION

Gas sensors have been designed for the first time 70 years ago. At the beginning of the 1950s, two scientists working at Bell Laboratories discovered that the resistance values of some semiconductor materials changed when they were in contact with the atmosphere. At the beginning of the 1960's, ZnO was used as a thin film sensing layer and was discovered to be able to detect gas with simple electrical devices. A chemo resistive device with ZnO thin films capable of operating at 485 °C was designed. The response of the sensing system to propane was 100 times higher than the thermal conductivity detector used at that time. In 1967, it was defined how the effects of modified semiconductors were changed by the addition of noble metals (eg Pt, Pd, Ir, Rh). Since then, the sensitivity and selectivity of semiconductor sensing devices have been significantly improved, and intensive research into new formulations to detect materials has been intensified.

Carbon monoxide (CO) gas is a colorless, odorless and tasteless gas with a very toxic. Unfortunately, we do not recognize this gas with our sense organs. This gas, which is generally a result of incomplete combustion, unfortunately infiltrates from the stoves and causes hundreds of people to lose their lives in our country. The person who is exposed to carbon monoxide gas can not leave the place where he knows that he will die after a certain period of time. This gas, which is extremely deadly, has not been adequately countered in our country and in many foreign countries.

Gas sensors started to be used in the 19th century to the 20th century has entered our homes for measurement of gas quantities in the mid-1980s. Gas measurement can be done with many different methods, but the most widely used types are the ones which are measured by infrared rays with the most accurate result and the ones which are separated by heating the air are cheaper. Sensors are used to detect all flammable gases including carbon monoxide which is the biggest danger, and when they reach dangerous levels, it gives audial or visual alarm.

In the last thirty years, an increase on gas sensors has been observed in various applications such as home security, industrial and vehicle emission control, agriculture and biomedical as they can be integrated into small size and electronic devices. With the emerging nanotechnology, improvements have been made in sensor design such as more modest power requirement, lower weight, and smaller size.

Nowadays, smart home systems have become a subject that we are very familiar. Smart home is the union of technologies and services applied to homes, offices and small buildings to provide security, comfort, communication and power saving with less human interaction. These systems include lighting control, remote control, telephone systems, security systems, motion detectors, heating and cooling systems control.

A smart house is a structure that brings flexibility to the highest level by using various systems together in a coordinated manner to reduce technical performance, investments and operating costs.

The main difference of our thesis work is that when the flammable gas and carbon monoxide reach critical levels for respiration, our sensors send signals

to our Smart House Systems and automatically take necessary precautions in the house.

The work carried out within the scope of our project will make people's life easier; will aim to take heating system, cooling system, ventilation system, and so on under control. Due to the fact of these controlled systems, people live happy, peaceful and less stressful life.

If any of temperature, humidity, CO concentrations, cigarette and fire smoke, CNG (methane) and natural gas odor levels reach to the threshold level in the house; the device we designed which is going to send a signal to the smart home application which will control the air conditioner, aspirator, ventilation, oven and so on in the smart house.

The device we designed in our thesis work can be developed for industrial utilities and offices to provide a healthy business environment by minimizing work accidents and determining appropriate illumination for utility/ office.

Not only the measured quantity will be sent as an analog signal, but the current LED display will show the values instantly, and because of the buzzer, the people in the area will be alerted to move away.

II. DESIGN OF GAS SENSOR SYSTEM

Control card:

Ease of programming and resource richness are taken into account while the selecting the microcontroller to be used in the project. Microcontrollers' internal structures are so complex that they can be used more efficiently through a simpler software language. The Arduino MEGA 2560 R3 microcontroller has all of these features.

Figure 1. Arduino Mega 2560 Front and Rear Sections

Arduino Mega 2560 has 54 digital input / output pins. 15 of them can be used as PWM output. There are also 16 analog inputs, 4 UART (hardware serial port), one 16 MHz crystal oscillator, USB connection, power jack (2.1mm), ICSP header and reset button. Arduino Mega 2560 includes all of the components required to support a microcontroller. Arduino Mega 2560 can be connected to a computer, powered by an adapter or battery. The Arduino Mega R3 (revision 3) has the following additional features :

TABLE 1:ARDUINO MEGA TECHNICAL SPECIFICATIONS

Microcontroller	AT Mega 2560
Operating voltage	5V
Feeding Voltage (Recommended)	7-12V
Feeding Voltage (Limit)	6-20V
Digital I / O Pin	54 (14ü PWM outlet)
Analog Input Pin	16
I / O Pin Current	40 mA
3.3V Pin Current	50 mA
Flash drive	256 kB
SRAM	8 kB
EEPROM	4 kB
Clock frequency	16 MHz

Sensors:

Sensors; are electrical devices for collecting information in the current environment. The data coming to the sensors turn into electrical signals through Transducers. Sensors can be classified in two groups, analogue and digital. Analog Sensors: sensors that can take values from the sensor output anywhere along the time-amplitude axis. Digital sensors are binary-based sensors that produce 1 and 0 at the output.

Sensors used in the project; MQ-2 combustible gas and cigarette smoke sensor, MQ-4 methane gas (CNG) sensor, MQ-9 carbonmonoxide sensor, DHT11 humidity sensor and DS18B20-T092 DIP temperature sensor.

The purpose of selecting analog sensors in the project; it is easier to use than digital sensors. The price / performance ratio between digital and analog sensors shows that analog sensor usage is more reasonable.

The Arduino microprocessor is a digital-based hardware. For the microcontroller to detect this data, the analog data from the sensors must be converted into digital data form. For this, Arduino has an ADC on its own. This analog signal is converted into a digital signal through a 10-bit quantizer. The sampling frequency is fixed at 10 KHz in the Arduino library. If requested, the sampling frequency can be increased or decreased by entering the Arduino library. The maximum voltage can be measured at Arduino's analog pins is 5 volt.

Combustible Gas and Cigarette Smoke Sensor (MQ-2):

MQ-2 Gas and Smoke Sensor is a sensor module that detects the presence of gas in the air and measures the concentration and outputs it as analog voltage output. The sensing material of the MQ-2 gas sensor is SnO2, which has low conductivity in clean air. When the target combustible gas is present in the air, the conductivity of the sensor is greater with increasing gas concentration. The gas concentration ranges from 300 ppm to 10000 ppm. MQ-2 Flammable Gas and Smoke Sensor can operate between -100C and 500C and receive less than 150mA with 5V supply. It has high sensitivity against LPG, Methane, Propane, Hydrogen and flammable steam and has low cost.

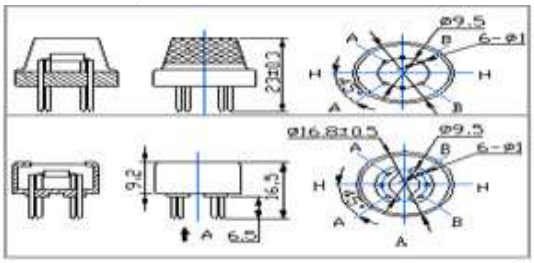

Figure 2. MQ-2 Gas Sensor Outside View and External Measures

TABLE 2 :MQ-2 SENSOR TECHNICAL SPECIFICATIONS

Sensor Type			Semiconductor
Standard Encapsulation			Bakelite (Black Bakelite)
Circuit	Cycle Voltage	V_C	≤24V DC
	Heater Voltage	V_H	5.0V±0.2V AC or DC
	Load Resistance	R_L	Adjustable
Character	Heater Resistance	R_H	31Ω±3Ω（Room Temp.）
	Heater Consumption	P_H	≤900mW
	Sensing Resistance	R_S	2KΩ-20KΩ (at 2000 ppm C_3H_8)
	Sensitivity	S	R_s(air)/R_s(1000ppm isobutane)≥5
	Slope	α	≤0.6($R_{3000ppm}/R_{1000ppm}$ CH_4)
Environment	Humidity		20℃±2℃; 65%±5%R_H
	Standard Test Circuit		V_c:5.0V±0.1V; V_H: 5.0V±0.1V
	Preheating Time		More than 48 hours

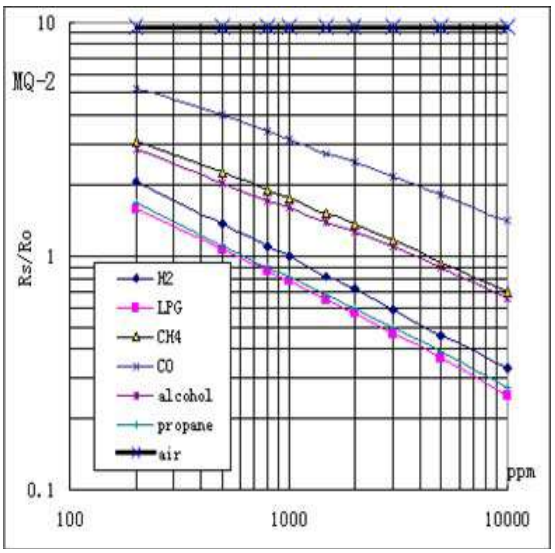

Figure 3.MQ-2 Sensitivity Features

Figure 3 shows the typical sensitivity characteristics of MQ-2, the resistance ratio of the sensor (Rs / Ro) and the concentrations of the gases. Rs meanss the resistance of different gases, while Ro is the resistance of the sensor at 1000 ppm Hydrogen.

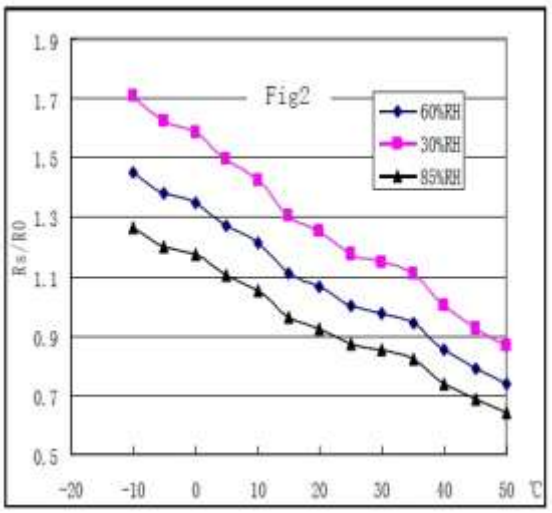

Figure 4.MQ-2 Change Against Temp. and Humidity

Figure 4 shows the typical temperature and humidity characteristics of MQ-2 and the resistance ratio (Rs / Ro) of the sensor. While Rs expresses resistance at different temperature and humidity values of 1000 ppm butane, Ro shows resistance to 1000 ppm 20 ° C / 65% R_H Methane.

Methane Gas (CNG) Sensor (MQ-4):

The MQ-4 methane gas sensor detects the presence of methane (CNG) natural gas at a range of concentrations suitable for gas leak detection between 300 ppm and 10000 ppm and outputs analog voltage according to the gas density.The sensing material of the MQ-4 gas sensor is SnO2, which has low

conductivity in clean air. When the targeted methane gas is present in the air, the conductivity of the sensor is higher as the gas concentration increases. It is highly sensitive to methane, propane and butane, and has low cost.

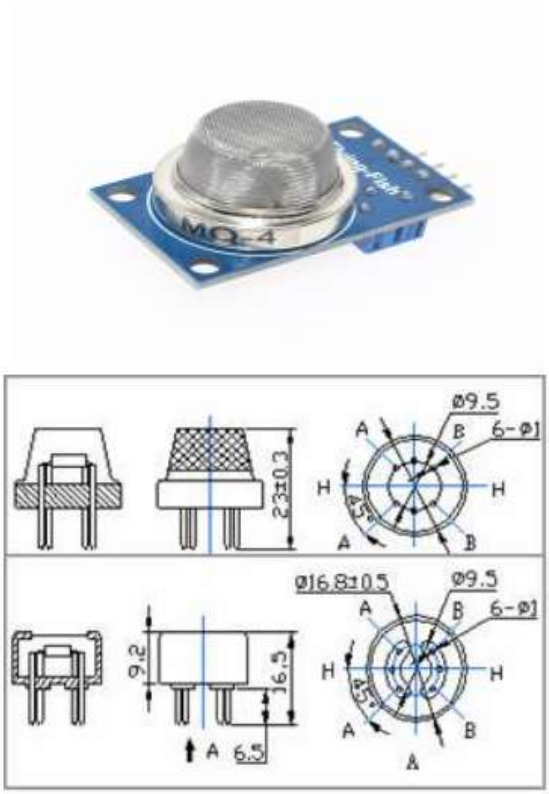

Figure 5.MQ-4 Gas Sensor Outside View and External Measures

TABLE 3 : MQ-4 SENSOR TECHNICAL SPECIFICATIONS

Sensor Type			Semiconductor
Standard Encapsulation			Bakelite(Black Bakelite)
Circuit	Cycle Voltage	V_C	≤24V DC
	Heater Voltage	V_H	5.0V±0.2V AC or DC
	Load Resistance	R_L	Adjustable
Character	Heater Resistance	R_H	28.5Ω±3Ω（Room Temp.）
	Heater Consumption	P_H	≤900mW
	Sensing Resistance	R_S	2KΩ-20KΩ (at 5000 ppm CH_4)
	Sensitivity	S	R_s(air)/R_s(5000ppm CH_4)≥5
	Slope	α	≤0.6($R_{5000ppm}$/$R_{3000ppm}$ CH_4)
Environment	Humidity		20℃±2℃；65%±5%R_H
	Standard Test Circuit		V_C:5.0V±0.1V; V_H: 5.0V±0.1V
	Preheating Time		More than 48 hours

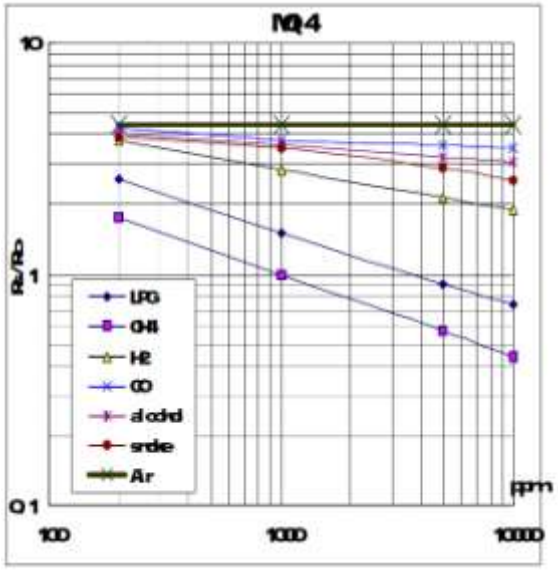

Figure 6.MQ-4 Sensitivity Features

Figure 6 shows the typical sensitivity characteristics of MQ-4 at 20 °C, 65% humidity, 21% O2 concentration of different gases. Rs means the resistance of different gases, while Ro is the resistance of the sensor at 1000 ppm methane in fresh air.

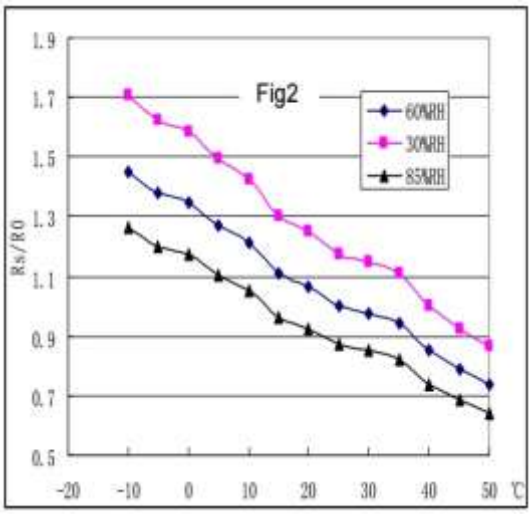

Figure 7.MQ-4 Change Against Temp. and Humidity

Figure 7 shows the typical temperature and humidity characteristics of MQ-4 and the resistance ratio (Rs / Ro) of the sensor. While Rs indicates resistance at different temperature and humidity values to 1000 ppm Methane, The Ro shows 1000 ppm 20 ° C / 65% R_H resistance to Methane.

Carbon monoxide (CO) Sensor (MQ-9):

The MQ-9 CO gas sensor detects the presence of CO at a range of concentrations between 10 ppm and 1000 ppm suitable for gas leak detection and outputs analog voltage according to the gas density. The sensing material of the MQ-9 gas sensor

is SnO2, which has low conductivity in clean air. When the targeted carbon monoxide gas is present in the air, the conductivity of the sensor is greater with increasing gas concentration. It has high sensitivity to methane, propane and carbon monoxide and has low cost.

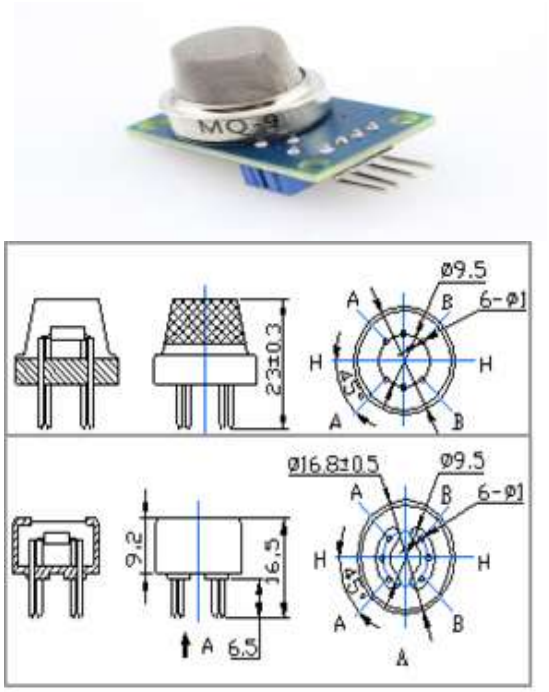

Figure 8. MQ-9 Gas Sensor Outside View and External Measures

TABLE 4 : MQ-9 SENSOR TECHNICAL SPECIFICATIONS

Sensor Type			Semiconductor
Standard Encapsulation			Bakelite
Circuit	Cycle Voltage	V_C	≤10V DC
	Heater Voltage	V_H	5.0V±0.2V AC or DC
	Heating Time	T_L	60±1S (High) 90±1S (Low)
	Load Resistance	R_L	Adjustable
Character	Heater Resistance	R_H	31Ω±3Ω（Room Temp.）
	Heater Consumption	P_H	≤350mW
	Sensing Resistance	R_S	2KΩ-20KΩ (at 100 ppm CO)
	Sensitivity	S	R_s(air)/R_s(100ppm CO)≥5
	Slope	α	≤0.6(R_{300ppm}/$R_{1000ppm}$ CO)
Environment	Humidity		20℃±2℃; 65%±5%R_H
	Standard Test Circuit		V_c:5.0V±0.1V; V_H: 5.0V±0.1V V_H: 1.5V±0.1V
	Preheating Time		More than 48 hours

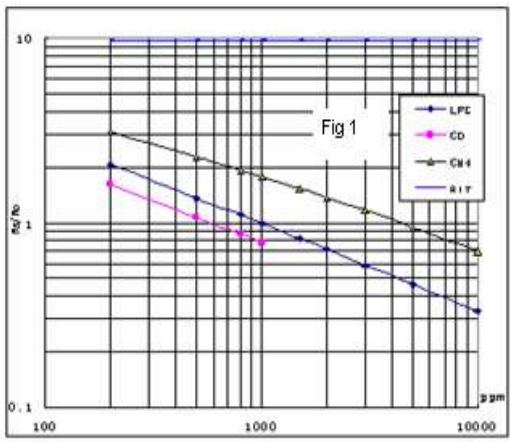

Figure 9.MQ-9 Sensitivity Features

Figure 9 shows the typical sensitivity characteristics of MQ-9, the resistance ratio of the sensor (Rs / Ro) and the concentrations of the gases. Rs meanss the resistance of different gases, while Ro is the resistance of the sensor at 1000 ppm LPG in clean air.

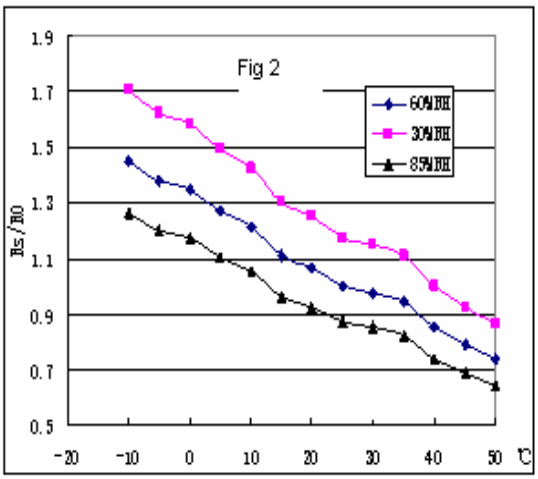

Figure 10 MQ-9 Change Against Temp. and Humidity

Figure 10 shows the typical temperature and humidity characteristics of MQ-4 and the resistance ratio (Rs / Ro) of the sensor. Rs shows resistance to different temperature and humidity values of 1000 ppm of Propan while Ro shows resistance to 1000 ppm of Propane at 20 ℃/ 65% R_H.

DHT11 Humidity Sensor:

DHT11 is an advanced temperature and humidity sensor unit that provides calibrated digital signal output. There is an 8 bit microcontroller on it and the product has a short response time. The sensor has a precise calibration and the calibration coefficient OTP is stored on a program of some kind in memory. It refers to this constant stored in the memory during product sensing.

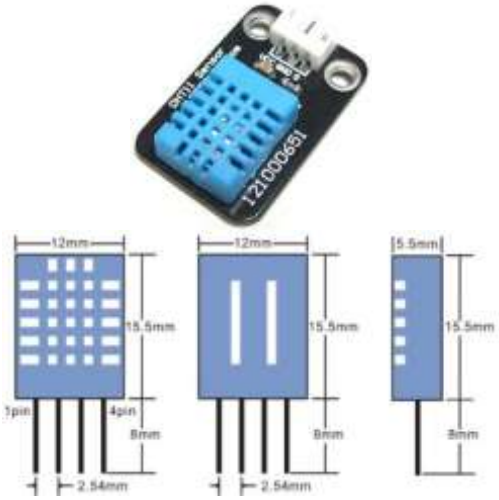

Figure 11.DHT11 Sensor Outside View and External Measures

Measures temperature between -40 °C and 80 °C with +/- 2 °C error, and can measure humidity between 20-90% RH +/- 4% RH (max. 5%). As a sensor measurement, the measurement results can be taken from the data acquisition period of the sensor in 2 second periods. In addition, the legs aligned in the same line facilitate the connection. A pull-up resistor is needed between Vcc and the output pin. For this reason, it must be used with a resistance between 4.7K and 10K.

TABLE 5:DHT11 SENSOR TECHNICAL SPECIFICATIONS

Parameters	State	Min.	Norm.	Max.
HUMIDITY				
Resolution		%1 RH	%1 RH	%1 RH
Repeatability			±%1 RH	
Precision	25℃		±%4 RH	
	0-50℃			±%5 RH
Measurement Range	0℃	%30 RH		%90 RH
	25℃	%20 RH		%90 RH
	50℃	%20 RH		%80 RH
Reaction time	1/e(63%)25℃, 1m/s Air	6 s	10 s	15 s
Delay			±%1 RH	
Long-term Stability	Normal		±%1 RH/yıl	
TEMPERATURE				
Resolution		1℃	1℃	1℃
		8 bit	8 bit	8 bit
Repeatability			±1℃	
Precision		±1℃		±1 ℃
Measurement Range		0℃		50 ℃
Reaction time	1/e(63%)	6 s		30 s
Power source	DC	3V	5V	5.5 V
Current Supply	Measured	0.5 mA		2.5 mA
	Average	0.2 mA		1 mA
	On Hold	100uA		150 uA

DS18B20 Temperature Sensor:

The DS18B20 sensor is a digital output temperature sensor with programmable resolution. Temperature measurement can be made with ± 0.5 °C tolerance between -10 °C and 85 °C. The features of the DS18B20 are as follows.

TABLE 6:DS18B20 SENSOR TECHNICAL SPECIFICATIONS

Parameters	Symbol	State	Min.	Norm.	Max.	Unit
Feeding Voltage	V_{DD}	Local Power	+3.0		+5.5	V
Pull-Up Supply Voltage	V_{PU}	Interference Power	+3.0		+5.5	V
		Local Power	+3.0		V_{DD}	
Thermometer Error	t_{ERR}	-10°C - +85°C			±0.5	°C
		-55°C - +125°C			±2	
Input 0 bit	V_{IL}		-0.3		+0.8	V
Input 1 bit	V_{IH}	Local Power	+2.2		Lower than 5.5 or V_{DD} + 0.3	V
		Interference Power	+3.0			
Bottom Current	IL	V_{IO} = 0.4V	4.0			mA
Waiting Current	I_{DDS}			750	1000	nA
Active Current	I_{DD}	VDD = 5V		1	1.5	mA
DQ Input Current	I_{DQ}			5		µA

Another characteristic of the DS18B20 sensor, shown in Figure 12, is the 1-Wire communication protocol of the maximally integrated company. This protocol is an asynchronous communication protocol used in the products of Maxim Integrated Company.

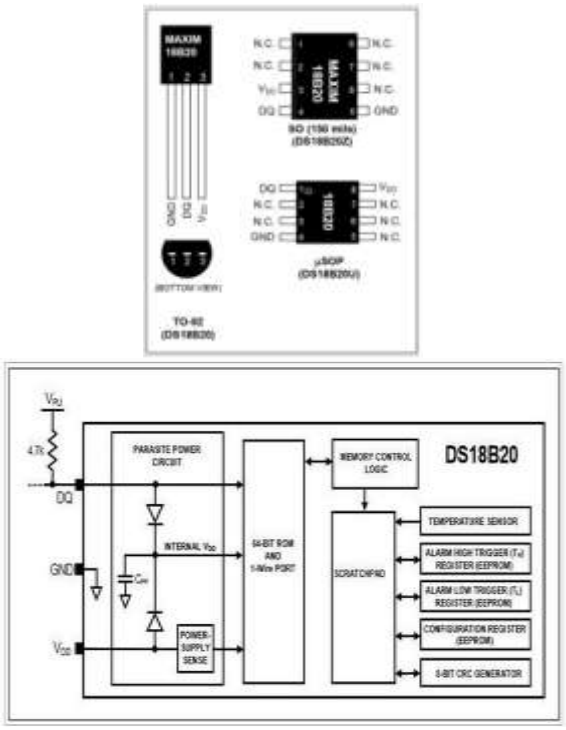

Figure 12. DS18B20 Package Structure and Interior

5V Relays:

A relay is an electromagnetically operated circuit element. It is an electrical switch that allows another electric circuit to be turned on and off when current is passed through it. This switch is controlled by an electromagnet. Relay is composed from three parts: Coil, Pallet and Contact. The coil part is the entrance to the relay. The pallet and contact part have no electrical connection to the coil.

Small currents and voltages provide greater current and voltage control. At the same time, relays are able to control electrical and electronic circuits of many different characteristics by switching without being affected by different frequencies and wave types. NO contact: means Normally open contact. It's an open circuit. Means logic 0. NC contact: Means normally closed contact. It's closed. It means logic 1.

Figure 13. 5V Relay Module

A total of 7 relays were used in our thesis work. If we think that there is Smart Home System Automation at the NO contact of these relays, the key remains open and the ventilation / air conditioning / hood is not active unless power is applied to the coil ends of the relay. But when the coil ends are energized, a magnetic field is formed. This magnetic field activates the electromagnet and the contact closes. As a result, the ventilation / air conditioning / hood becomes active.

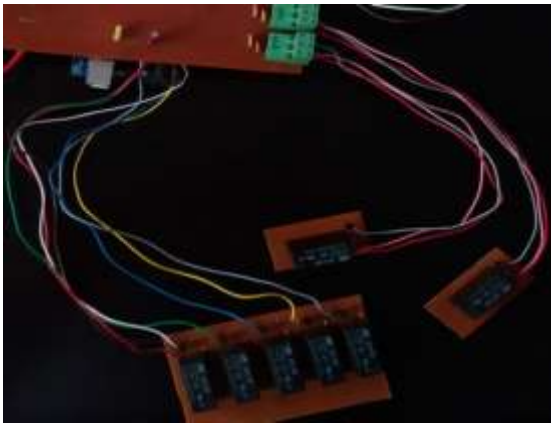

Figure 14. Relays used in the Thesis Work

III. DESIGN BLOCK DIAGRAM AND ALGORITHM

Figure 15 shows a block diagram prepared for the control of our device. In this project, the temperature, humidity, gas quantities which are affecting the sensors change the voltage values and these voltage values are transferred to the microcontroller. Analog data transmitted to microprocessor is converted into a digital signal by the ADC and sent to the related equipment over the relays.

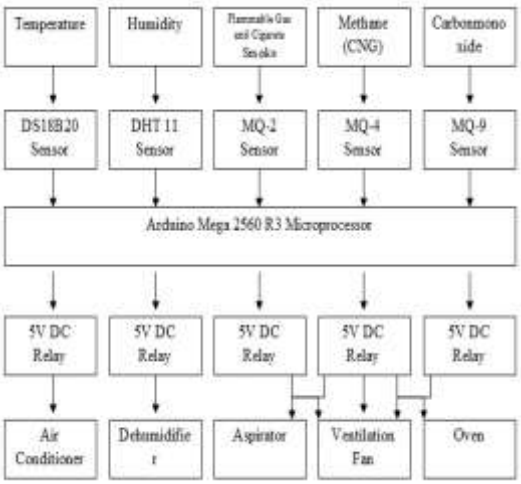

Figure 15. Block Diagram of Our Device

Figure 16 shows our device's algorithm. As it can be understood through the algorithm, we have LED light and relay which turns to active state in case of measurement above the set value of each sensor in

our device. The Buzzer and Emergency Relay are active if one of the sensors are above the set value. If the measured value is lower than the set value, the Everything-Is-Normal Relay becomes active.
As will be discussed in detail in the Conclusion and Discussion section, our received signal from the Emergency Relay of our device is suitable to receive rapid reaction in case of emergency with functions such as Wi-Fi communication or sending SMS to the phone of the host.

Figure 16. System Algorithm

IV. CONCLUSION AND DISCUSSION

Systems based on the communication of white appliances and systems to each other exist in the world and they are produced and sold in modular base by some companies especially in Europe and Far East. Because our gas detector system can be upgraded, the costs of high-cost systems can be reduced to make it particularly accessible for white appliances of small to medium price range.

Raspberry Pi is a minicomputer based on the ARM processor that was originally designed to develop young programming skills and to acquire skills in computer education at Cambridge University. It's a mini computer, because Raspberry pi is a complete computer with a keyboard, mouse and a display unit connected to it. Starting with Raspberry Pi Foundation in 2009, Raspberry Pi was introduced to PCs mainly for students who are not able to buy a desktop PC. However, thanks to the use of gpio pins, to communicate with electronic systems, its been integrated to a new field in electronics and mechatronics.

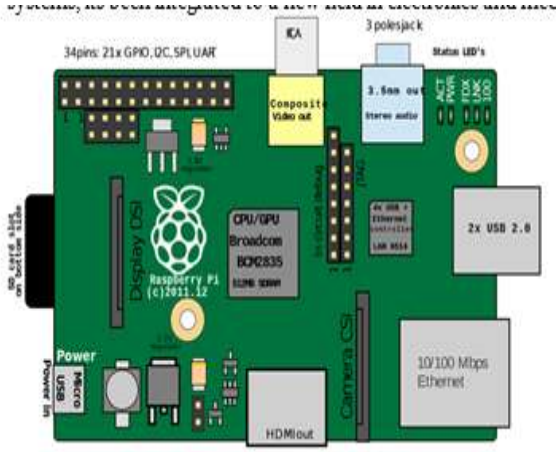

Figure 17. Raspberry Pi Component Placement

Raspbian operating system is a Linux distribution that runs only on Raspberry Pi. Raspbian is a free Debian based operating system optimized for Raspberry Pi hardware. This operating system consists of a set of basic programs and utilities that run Raspberry Pi. However, Raspbian offers more than a pure operating system:

- Safe data exchange can be performed by using in automation systems
- It is an open source software, therefore, it can be developed.
- Distant networks can be connected to each other by point to point method or client to server method.

With the increase of data transmission speeds, the rapid proliferation of data communications such as M2M and cellular networks has opened up the possibility of transmitting large amounts of data online from mobile units. As a result, rich information from mobile objects is now accessible from just about anywhere with a browser and an Internet connection.

With a program written on the Raspberry Pi development card, the necessary information can be obtained from the sensors and made to be wirelessly transmitted to the relevant address.

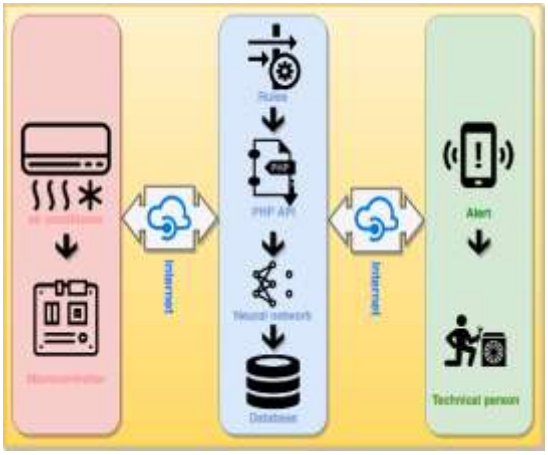

Figure 18. Server Communication Module

Moreover, by adding the RS232 serial communication port to our thesis work, an automatic message can be sent to landlord or fireman's phone in an emergency by adding a SIM900a-based GSM module, which can communicate with the phone and other devices and communicate via SMS.

Figure 19.SIM900A GSM Module

GSM stands for Global System for Mobile and is a worldwide standard that activates their connections with any mobile network in the world. If the advantage of using a GSM connection with a system or a machine is compared with any wireless connection, it is not important how long the wireless system can be sustained in the cellular coverage area provided for the device and the user, the user can control.

GSM module can be interfaced using the serial port of the Arduino card and communication can be achieved using TTL logic levels. The Max232 IC is used to perform bidirectional conversion between RS232 and TTL logic levels. Arduino card is connected to the Rx pin in Max232 on the Tx pin GSM module and the Tx pin on the Arduino's Rx pin GSM module is connected using Max232.

The code written in the Arduino can communicate with the GSM module using AT commands. AT commands received or sent from the module using the serial communication functions are provided by the Arduino library.

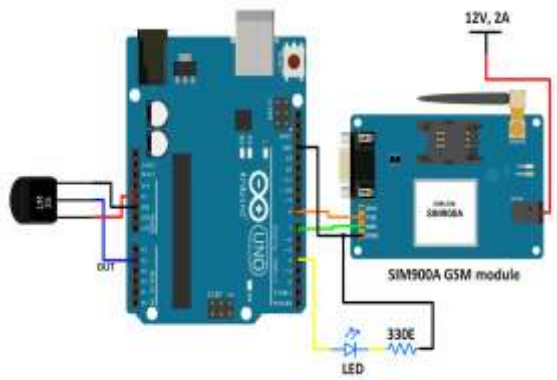

Figure 20. Connection Interface between SIM900A GSM Module and Arduino

IV. RESULTS

Our project will ensure that CO constructions, cigarette and fire smoke, CNG (methane) and natural gas odors are noticed in case of a possible leak.

Our IOT supported gas detector system is designed and activated to detect these gases and alert accordingly. As a result of the tests we have done, we have seen our device performed correctly. As mentioned earlier, we are alerted to the situation that passes five different threshold values. The alarm types we used are LED as visual and buzzer as audial.

We have performed our tests and we reached the results we were aiming. When we bring the carbon monoxide and CNG (gaseous) gases closer to the sensor or when the temperature and humidity of the environment in which the detector is located exceeds the threshold values, the LED lights of the respective sensors are illuminated and we have received a visual warning. Right after that, our gas detector began to tease the buzzer and we received our audible alert. Subsequently, the microcontroller energized the 5V relay connected to the relevant sensor and sent our DC signal. Thus, we have obtained the correct result from our tests.

We designed and displayed the alarm condition to alert the scope of this project in terms of cost aspects. Moreover, another good point of our project is that designed device is completely upgradable for further projects. If we will increase our costs by using more advanced techniques; With a program written on the Raspberry Pi development card, it is possible to acquire the necessary information of the household consumable white appliances from the sensors and to deliver it wirelessly.

Nowadays, it is possible to get an easy and economically affordable communication environment for the machines to communicate between themselves and at the machine management level.

Moreover, adding a SIM9000-based GSM module capable of dialing and telephoning via telephone and other devices; an automatic message can be sent to landlord or fireman's phone in an emergency by using the RS232 serial communication port.

This communication environment , has a structure that can transfer the needed information at the communication speeds of today's industry level within Industry 4.0

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