Fire detection and alarm system

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ABSTRACT

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ABSTRACT

The central target of the thesis project was to study, analyse and design a fire detection and alarm system. This topic was suitable because it covered a basic and important aspect in our modern life. The author has gained the valuable experience in the field of fire detection and alarm system from studying and conducting the project.

The objectives of the project were to provide information on fire alarm system in Vietnam and Finland, to show the similarities and differences with systems in both countries. Secondly, in the practical part, the objective was to build a demo system to demonstrate how a basic fire alarm system works.

To achieve the purpose of this thesis, the author studied the main standards on fire detection and alarm systems in Vietnam and Finland. For the practical part, Arduino Uno was used as the control unit with other necessary components.

Upon completing this project, the author has demonstrated how a fire detection and alarm system works and analysed the system standards in the above-mentioned countries. Moreover, the fire alarm system using the Arduino Uno was tested and found to work successfully.

Keywords Fire detection and alarm system, standards in Vietnam, standards in Finland, Arduino Uno

Pages 56 pages including appendices 7 pages

CONTENTS

1 INTRODUCTION

In our modern life, fire protection has become a top concern, because there are always fire hazards around us that can cause a great loss of property and human life. Therefore, having a fire alarm system played an important role, which help prevent and handle in time the fire when it occurred. Fire detection and alarm systems (FDAS) are all structured and introduced with the same fundamental target in mind: to discover a fire; effective alarm and provide information to the inhabitants; warn and give information to first responders. How these objectives are satisfied is depend on the particular situations – and also, the standard of the area of the world under consideration.

A fire alarm system is one of the basic systems that is required to be installed in every household and building in many countries. Having the system installed helps alert people of a possible fire, give them early warnings; automatically call the emergency services and contacts, minimize the time it takes for the fire department to come; lower the risks of false fire alarm; in the event of fault, it can tell the exact problem, it also can have reduced fire damage to property.

Because of the importance of fire alarm systems, this thesis was made. This thesis has three main parts. The first part presents the history of fire detection and alarm systems. This part helps readers understand how the first fire alarm system started. For the purpose of gaining knowledge about fire detection and alarm system, the author provides its standards in Vietnam and Finland in the second part. The reason the author chose these two countries is because Finland is where the author is residing at the moment and Vietnam is the author's home country. Also, a comparison between both standards is shown to give a better view of how the system works and the requirements in different countries. The final part consists of making a fire alarm system by using Arduino Uno to demonstrate how the system operates.

The thesis was supervised by HAMK professors. Thanks to their guidance and advice, this thesis was carried out successfully.

2 FIRE DETECTION AND ALARM SYSTEM

2.1 History of fire alarm systems

A fire alarm system includes components operating together to detect and alarm people by visual and audio methods when smoke, fire, or other dangers are occured. It also can notify the fire department and control all the fire alarm devices in the area. That's how we see it nowadays.

However, fire alarm system has not only been around recently, but it has been existed for a long time. According to Life Safety Consultants website, the first fire alarm system was invented in 1852 by Dr. William F. Channing and Moses Farmer. The system comprised of two fire alarm boxes that had a telegraphic key and a handle each. If a fire was found in a home or business, somebody would need to reach inside one of the boxes and wrench the handle so that it can send an alert to a close-by alarm station. An operator at the station would then take the message and notify the fire department so that they could send help. It was a significant procedure and required several steps. (Life Safety Consultants, n.d.)

The first electric fire alarm system was invented in 1890 by Francis Robbin Upton, an accomplice of Thomas Edison. He perceived that, most of the time, people wouldn't have time to remain around and wrench a handle is the case of fire. Therefore, his electric system disposed of the requirement for this progress. Surprisingly, the plan for his system was not that popular when it was first presented, but after some time, people started to understand the need for a more developed fire alarm system like this one. (Life Safety Consultants, n.d.)

Since then, with the technology advancing, fire alarm system is ever evolving. Being one of the most important system in modern life, the field of fire alarm system has always been developing. In the future, it may be one of the main focuses of smart house technology. (Life Safety Consultants, n.d.)

2.2 Value of fire alarm systems

The importance of fire alarm system is unquestionable. To demonstrate its importance, here are some statistics about smoke alarm in the U.S:

According to estimates by the National Fire Protection Association and the U.S. Fire Administration, U.S home use of smoke alarms ascended from less than 10% in 1975 to at least 95% in 2000, while the quantity of house fire deaths was decreased almost by half. Therefore, the home smoke alarm is recognized as the greatest success in fire safety near the end of 20th century, because it alone represented a highly effective fire safety technology with the ability to face most of the fire death problem that being used nearly universal. Smoke alarms give an early warning of a fire, giving people more escape time. In 2012-2016, smoke alarms were present in three fourths (74%) and set off in more than half (53%) of the home fires reported to U.S. fire departments. Almost three of every five home fire casualties came from fires in homes do not have smoke alarms installed (40%) or with smoke alarms that were not operating (17%). The mortality ratio per 1,000 notified home fires was more than double rate as high in homes that did not have any operating smoke alarms (12.3 deaths per 1,000 fires), either because smoke alarm was not installed or an alarm was installed but malfunction), as it was in homes with working smoke alarms (5.7 per 1,000 fires). In fires in which the smoke alarms were installed but did not work, more than two-fifths (43%) of the smoke alarms had no or loose connected batteries. Also, dead batteries created one-quarter (25%) of the smoke alarm malfunctions. (National Fire Protection Association, 2019).

These figures help further highlight the significance of having a fire alarm system, as having one would prevent and reduce casualties and property damage to the fire. Furthermore, have a fire alarm system installed makes people feel safer and make your mind at ease as it reduces the threat of fire.

3 GENERAL INFORMATION ON FIRE DETECTION AND ALARM SYSTEMS IN FINLAND AND VIETNAM

3.1 In Finland

In Europe, the Comité Européen de Normalisation or European Committee for Standardization in English (CEN), established European standards known as “EN” that are followed by 33 member countries, which adopted as a national standard. All of member countries publish the EN standards with adjustment as well as standards for the specific nation, for example, the Suomen Standardisoimisliitto, or Finnish Standards Association (SFS) in Finland. This thesis contains the Finnish Standards (SFS) version of EN 54 - Fire detection and alarm systems, which presents specific instructions and suggestions for the design and installation of fire alarm systems.

In Finland, Finnish Safety and Chemicals Agency (Turvallisuus- ja kemikaalivirasto in Finnish - Tukes), which is an agency within the Ministry of Employment and Economy of Finland, provides guidelines for fire detection and alarm system. According to Tukes website regarding to the installation and maintenance of fire alarm system, it may only be executed by companies whose qualification has been verified. There is a list of installation companies available on the website. Also, the website states that before the start of installation, the company must inform Tukes and assign qualified responsible person to perform tasks related to fire alarm systems. (Finnish Safety and Chemicals Agency, n.d.)

Maintenance and inspections are considered as fitting when a person in charge of fire alarm system maintenance is selected and a maintenance program is prepared based on the system supplier’s maintenance instructions and this program is also carried out. Routine inspections are normally scheduled to take place at 3-year interims. The interim is decided in a document, for example, the maintenance instructions given by the manufacturer. (Finnish Safety and Chemicals Agency, n.d.)

Examinations related to fire alarm systems are arranged by company named Kiwa Inspecta Oy, which is assessed by the Finnish Safety and Chemicals Agency (Tukes). Kiwa Inspecta is a company specialized in inspection, testing, provide certification and technical consultancy in Northern Europe. Its Finland branch is established in 1998 and belongs to the Kiwa Inspecta Group. (Kiwa, n.d.)

As declared on Tukes website, before a fire alarm system is taken into utilization, a certificated inspection body endorsed by Tukes must carry out an authorizing inspection. Furthermore, property developers/inhabitants must go into an alarm transmission arrangement concerns the connection of the fire alarm system’s alarm data to the local emergency response center and their picked teleoperator. In addition, they must manage trouble checking of alarm data sent to the emergency response center with their preferred operator and/or other service providers. Finally, they guarantee that the fire alarm systems are in operational state and have the system components kept up and inspected in compliance with the requirements set for the fitting level by law, which is Rescue Act 379/2011, §12. (Finnish Safety and Chemicals Agency, n.d.)

3.2 In Vietnam

In Vietnam, Vietnam Standards, shortened TCVN (Tiêu Chuẩn Việt Nam – the Vietnamese) are issued by Vietnam Standard and Quality Institute, part of the Directorate for Standards, Metrology and Quality of Vietnam (STAMEQ). The author of this thesis examined TCVN 7568 – Fire detection and alarm systems, which is based on ISO 7240 and provides a description of how to design, install, test and maintain an automatic fire alarm system in Vietnam. The minister of Public Security of Vietnam promulgates the guideline for construction, installation, inspection and maintenance of a fire safety system.

According to the ministry, concerning the construction and installation of fire safety systems, the Head and legal representative of the company must have qualifications and certificates of training in fire safety. These certificates and qualifications are licensed by the Fire department. There must also be at least one Commander who is in charge of construction of fire safety. The company must have operating places and facilities, vehicles, equipment, or machinery serving the construction and installation. The periodic and irregular inspection of fire safety systems is carried out by Head of facilities, Presidents of the People 's Committees of communes, property owners or householders within their area of competence. Fire departments shall perform periodic and quarterly inspection of facilities posing a risk of conflagration, perform biannually and annually inspections at other places. (Act on Decree No. 79/2014/NĐ-CP).

3.3 Analysis between both countries

After some researched about how a fire alarm system is monitored and managed in Vietnam and Finland, the author found some differences.

First of all, the Finnish standards are adopted from the European standards, which are reviewed and published by European Standardisation Organisations. Meanwhile, Vietnamese standards are based on the ISO standard body, which under the responsibility of ISO, is an independent, non-governmental organisation.

Secondly, in Finland, the Finnish Safety and Chemicals Agency-Tukes determines which companies or who can install and maintain fire alarm systems. These companies must have competence and the person who responsible for the job must have a qualification certificate verified and approved by Tukes. Also, the examination of the fire alarm system is carried out by a company called Kiwa Inspecta, which is approved by Tukes. Whereas in Vietnam, the head and legal presentative of the company in charge of installing and maintaining the fire alarm system must also have qualifications and certificates of training in fire safety, which are provided by the Fire department. Furthermore, when constructing a fire safety system, a fire commander must oversee the process. Also, the inspection and examination of the system are executed by the Fire department.

4 FIRE DETECTION AND ALARM SYSTEM STANDARDS IN VIETNAM AND FINLAND

4.1 Fire alarm system standard in Finland

The Finnish standard for fire detection and alarm systems is SFS-EN 54, which contains:

- SFS-EN 54-1:1996 – Part 1: Introduction
- SFS-EN 54-2:1997/A1:2006 – Part 2: Control and indicating equipment
- SFS-EN 54-4:1997/AC:1999 – Part 4: Power supply equipment
- SFS-EN 54-5:2017+A1:2018 – Part 5: Point heat detectors

- SFS-EN 54-26:2015 – Part 26: Carbon monoxide detectors – Point detectors

4.1.1 General

SFS-EN 54-1 states that the function of a fire detection and alarm system is to identify the fire at the earliest practicable moment; give signals and indications to people around with the goal that appropriate action can be taken; also give audible and/or visible signals to the occupants of the building who may be in danger from a fire.(SFS-EN 54-1,2011).

Additionally, the system is expected to operate satisfactorily not only under fire conditions, but also when faced any conditions to be met in practice. (SFS-EN 54-1,2011).

To accomplish the general functionality of a fire detection and alarm system, basic functions need to be implemented. Functions are performed by components which are interlinked using a transmission path (such as wire, radio communication or other suitable means) to achieve the overall design objectives of the fire detection and alarm system. To understand these functions, the author analyzed the functions according to Figure 1.

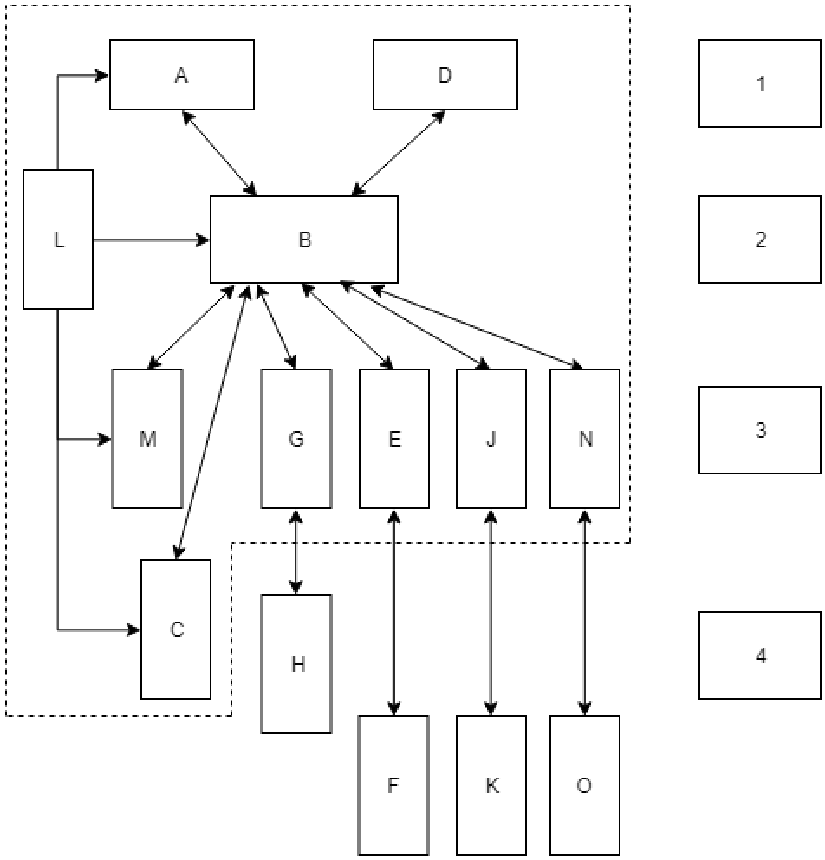
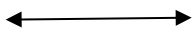


Figure 1. Fire detection and alarm system and associated systems, functions and equipment

Key to functions in Figure 1

1. Actuation functional group
2. Action functional group
3. Local functions associated with fire detection and alarm system
4. Remote functions associated with fire detection and alarm system

A. Detection function
B. Control and indication function
C. Fire alarm signal function
D. Manual initiating function
E. Fire alarm routing function
F. Fire alarm receiving function
G. Fire protection system/equipment control function
H. Fire protection function
J. Fault warning routing function
K. Fault warning receiving function
L. Power supply function
M. Fire alarm control and indication function
N. Ancillary input/output function
O. Ancillary management function



Exchange information between functions

It must be noted that the functions shown inside the dotted line are included within the fire detection and alarm system.

All the main functions (items A to O) are grouped to four function groups (item 1 to 4). The control panel (B) is the central part of the fire detection and alarm system. It monitors different alarm inputs from automation fire detection devices (A) such as flame detectors, smoke detectors, ... and manual initiating device (D) such as pull stations, call points, …, and then trigger alarm output devices like loudspeakers, warning lights, ringing bells, … (item C and M) when there are alarm signals sounded. The control panel also controls fire protection system or equipment, which is fire/smoke doors, smoke and heat control system, sprinkler, … (item G and H). It also responsible to check for faults in the system (item J and K) manage the ancillary equipment, for example cabinet, fire extinguishers, hose reel, … (item N and O) and maintain the connection of fire detection and alarm components (item E and F). The system is powered by power supply equipment (L).

4.1.2 Control and indicating equipment

The following abbreviation is used with the control and indicating equipment:
c.i.e.: Control and indicating equipment.

SFS-EN 54-2 provides that the c.i.e. shall be able to absolutely display the following functional conditions as:
- Quiescent condition
- Fire alarm condition
- Fault warning condition
- Disablement condition
- Test condition

The c.i.e. also must be capable of showing any combination of the conditions stated above, except quiescent condition, at the same time. At any time, any kind of system data shall be shown amid quiescent condition. Still, no indications shall be mistaken with indications used in other conditions. (SFS-EN 54-2, 2007)

The Finnish standard provides the basic principle and requirement of the conditions. With fire alarm condition, the c.i.e. would enter this condition when signals are received after necessary checking are read as fire alarm. Also, the c.i.e. must go in the fire alarm state within 10 s of the activation of any manual call point. In this state, it shall be able to perform receiving, processing and indicating signals from the zones. The signals from one zone must not be falsify with other zones. (SFS-EN 54-2, 2007)

One of the other conditions is fault warning condition, the c.i.e. would enter this condition when signals are received, after essential processing are interpreted as a fault. It must enter this condition within 100 s of the fault circumstance or the reception of a fault signal. (SFS-EN 54-2, 2007)

The disablement condition is one of two remaining condition. Disablement shall restrict all corresponding compulsory indications or outputs or both from the zones are being disabled, but shall not counteract other required indication and/or outputs from other unaffected zones. It must have planned to individually disable and re-enable each of the functions. And disablement and re-enablement shall not be affected by a reset from a fire alarm condition or fault warning condition. (SFS-EN 54-2, 2007)

The test condition is the final condition for c.i.e.. It shall be in this condition while one or more zones are under test. To enter and cancel the test state, it must be manually operated. It must be conceivable to test the operation of each zone separately. In test condition, zones in the test state shall not hinder the required indications and outputs from other zones that not in test state. (SFS-EN 54-2, 2007)

Another important aspect of the c.i.e. that mentioned in SFS-EN 54-2 is indication means and requirements. The first one is light- emitting indicators, mandatory indications shall be visible in an ambient light intensity up to 500 lux, at any angle up to 22.5° from a line through the indicator perpendicular to its mounting surface at 3 m distance for the general indications of function condition and the supply of power, or at 0.8 m distance for other indications. (SFS-EN 54-2, 2007)

The second means of indication is by alphanumeric displays. Major indication shall be legible for the lesser of 1 h or the duration of the standby power source, following the display of a new indication of fire or fault, at 0.8 m distance, in ambient light intensities from 5 lux to 500 lux, at any angle from the normal to the plane of the display up to 22.5° when viewed from each side and 15° when viewed from above and below. (SFS-EN 54-2, 2007)

The light-emitting indicators have colour requirements such as: red for indications of fire alarm, fire alarm routing equipment signals, automation fire protection equipment signals; yellow for indication of fault warning, disablements, zones in the test state, fault warning routing system signals and delays to outputs; green for the indication that the c.i.e. is supplied with power. The alphanumeric displays do not have to use different colours, however, if they do, the colours used would be same as stated above. (SFS-EN 54-2, 2007)

Lastly, audible indicators shall be a part of the c.i.e.. The same device can be used for fire alarm and fault warning indications. The minimum sound level at a distance if 1 m with any access door on the c.i.e. closed shall be either 60 dB for fire alarm indications and 50 dB for fault warning indications. The sound level should be measured in anechoic conditions (SFS-EN 54-2, 2007)

Figure 2 shows an example of a fire alarm system control panel.

Figure 2. Fire alarm control panel (Asenware, n.d.)

4.1.3 Power supply unit

The following abbreviation is used of the power supply unit:
p.s.e.: power supply equipment.

The general requirement as stated in SFS-EN 54-4 for p.s.e. is that there must at least two power sources for the power supply of a fire detection and alarms system: the main power source and the standby power source. The main power source should be intended to work from the public electricity supply or similar system. The main power source will be the sole source of power to the system, other than currents related with battery monitoring, when it available. If the primary power source fail, the p.s.e. shall be automatically switched over to a standby power source, when the primary power source is repaired, it shall be automatically switched back. Where a battery is utilized, the p.s.e. shall contain charging equipment to charge the battery and keep it up in a fully charged state. Finally, if one of the power sources is failed, it shall not cause the failure of any other power source or fail to supply power to the system. (SFS-EN 54-4, 1998).

The main power source's functions as described in Finnish standard are it should be able to operate in compatibility with its specification given in the manufacturer's data, regardless with the condition of standby power source. It may also be capable of supply any required charging current for the battery or batteries. Lastly, it may permit battery charging to be limited or cut off when it is delivering a short duration maximum output load. (SFS-EN 54-4, 1998).

The functions of the standby power source are pretty similar to the main power source. It must be able to work without concerning to the condition of the main power source. Moreover, it shall be rechargeable; suitable to maintained in a fully charged state; constructed for stationary use, marked with type designation and date of manufacture and have a safety mechanism to prevent explosion. (SFS-EN 54-4, 1998).

According to SFS-EN 54-4, the p.s.e. should be able to perceive and signal within 30 minutes of the occurrence of the accompanying faults: loss of the main power source; loss of the battery charger; reduction of the battery voltage to less than 0.9 of the final voltage and within 15 minutes of the event loss of the standby power source. (SFS-EN 54-4, 1998).

Figure 3 shows an example of the power supply unit used in the fire alarm system.

Figure 3. Power supply charger (Altronix, n.d.)

4.1.4 Point heat detectors

According to SFS-EN 54-5, heat detectors are classified by one or more of following classes: A1, A2, B, C, D, E, F or G depending on the alarm temperature and surrounding operating temperature. Each detector class has a static response and possibly have a rate of rise response. Manufacturers may optionally give additional information regarding the type of heat detector by adding the suffix S or R to the below classes. The affix R means that the detector has been examined and endorsed as a rate-of-rise detector, while the affix S means that the detector tested and accepted as a static detector (Apollo-fire, n.d.). Table 1 shows the heat detector classes.

Table 1. Detector classification temperatures (SFS-EN 54-5, 2018)

Detector class	Typical Application Temperature °C	Maximum Application Temperature °C	Minimum Static Response Temperature °C	Maximum Static Response Temperature °C
A1	25	50	54	65
A2	25	50	54	70
B	40	65	69	85
C	55	80	84	100
D	70	95	99	115
E	85	110	114	130
F	100	125	129	145
G	115	140	144	160

Figures 4 and 5 illustrate two heat detectors with separate classes

Figure 4. Series 65 A1R Heat Detector. (Apollo-fire, n.d.)

Figure 5. Series 65 BR Heat Detector (Apollo-fire, n.d.)

The general requirements the heat detector mentioned in SFS-EN 54-5 are each detector shall be constructed such that at least part of its heat sensitive element(s), except elements with auxiliary functions, shall be ≥ 15 mm from the mounting surface of the detector. Class A1, A2, B, C or D detectors shall be provided with an integral red visual indicator, by which the individual detector which released an alarm, may be identified, until the alarm condition is reset. Where other conditions of the detector may be visually indicated, they shall be clearly distinguishable from the alarm indication, except when the detector is switched into a service mode. Class E, F or G detectors shall be provided with either an integral red indicator, or with another means for locally indicating the alarm status of the detector. The visual indicator shall be visible from a distance of 6 m at an angle of up to 5° from the axis of the detector in any direction or 45° from the axis of the detector in at least one direction, in ambient light intensity up to 500 lux. (SFS-EN 54-5, 2018).

4.1.5 Carbon monoxide fire detectors

Carbon monoxide (CO) is a product of the incomplete combustion of carbon-based materials. The Finnish standard introduces that carbon monoxide fire detectors can react quickly to slow, smouldering fires including carbonaceous materials because CO does not depend solely on convection, but also moves by diffusion, and they can be better suited to applications where other fire detection methods are prone to false alarms, i.e. due to dust, steam and cooking vapours. SFS-EN 54-26 states that the CO fire detectors can only be used when a risk evaluation shows that they are suitable for detecting the kind of fires that may happen. (SFS-EN 54-26, 2015)

The main requirements of CO fire detectors presented in Finnish standard are: Each detector shall be given an integral red visual indicator, by which the individual detector that released an alarm can be distinguished, until the alarm condition is reset. Where other conditions of the detector can be visually indicated, these shall be clearly discernible from the alarm indication, with the exception of when the detector is changed into a service mode. The visual indicator shall be visible from a distance of 6 meters directly below the detector, in an ambient light intensity up to 500 lux. (SFS-EN 54-26, 2015).

Figure 6 shows a carbon monoxide fire detector.

Figure 6. Carbon monoxide/Smoke detector (CableOrganizer, n.d.)

4.2 Fire alarm system standard in Vietnam

As stated from above, the Vietnam standard for fire detection and alarm system is TCVN 7568. It contains five parts, including:

- TCVN 7568-1:2006 – Part 1: General and definitions
- TCVN 7568-2:2013 – Part 2: Control and indicating equipment
- TCVN 7568-4:2013 – Part 4: Power supply equipment
- TCVN 7568-5:2013 – Part 5: Point-type heat detectors
- TCVN 7568-6:2013 – Part 6: Point-type fire detectors for carbon monoxide.

4.2.1 General

TCVN 7568-1 specified that a fire detection and alarm system must be operated by automatic detection instruments or by manually triggered and must achieve its functions without failures or oversights, including

- Notice the threat quickly enough
- Sending the detection signal accurately to the control and indicating equipment, if applicable, the fire department
- Give a clear alarm signal that will attract the attention of inhabitants in a correct and instantaneous way
- Remaining sensitive to only danger conditions which its function is to notice and give warning about any supervised fault that may endanger the operation of the system.

Furthermore, that the system is obligated to work sufficiently not only in case of fire, but also during and after exposure to conditions prone to be met practically, for example corrosion, vibration, direct impact, indirect shock, and electromagnetic interference. The system is also must meet these addition requirements: can resist disturbance well, not affected by other systems installed together or separated, and not be cut down one part of the whole by fire before detecting the fire. (TCVN 7568-1, 2006)

How the functions of the fire detection and alarm system connect to each other and its associated systems that are stated in TCVN 7568-1 is shown in figure 7 below.

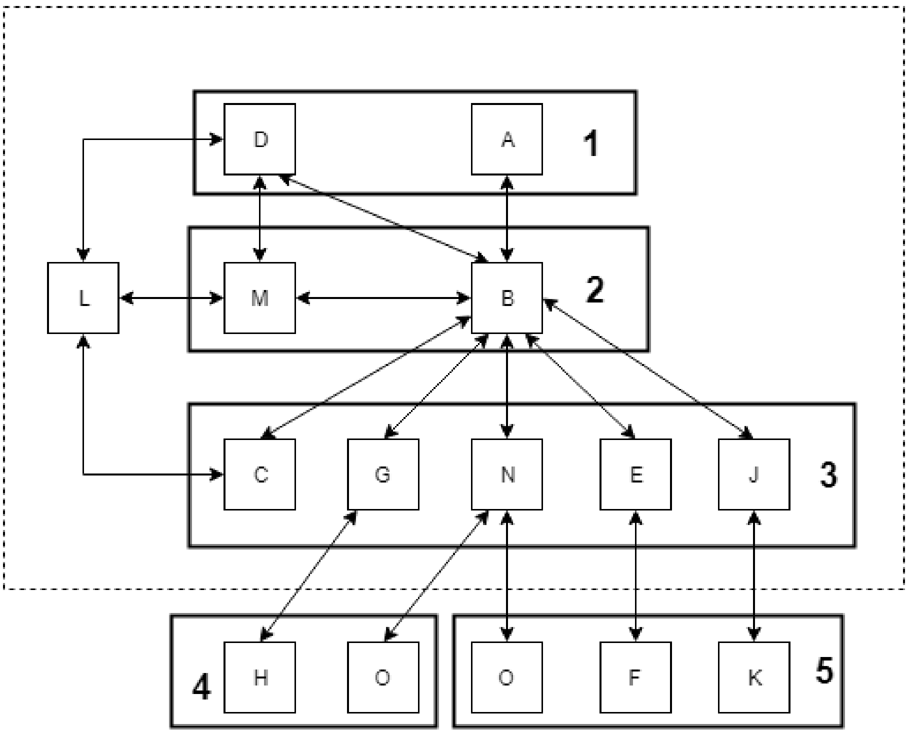


Figure 7. Fire detection and alarm system functions

Key to functions in figure 7

1. Actuation functional group
2. Control and indication functional group
3. Action functional group
4. Local functions associated with fire detection and alarm system
5. Remote functions associated with fire detection and alarm system

A. Detection function
B. Control and indication function
C. Fire alarm signal function
D. Manual initiating function
E. Fire alarm routing function
F. Fire alarm receiving function
G. Fire protection system/equipment control function
H. Fire protection function
J. Fault warning routing function
K. Fault warning receiving function
L. Power supply function
M. Fire alarm control and indication function
N. Ancillary input/output function
O. Ancillary management function

——— Functional group

------------------------ Functions included in the fire detection and alarm system

←——→ Exchange information between functions

All the main functions (item A to O) are grouped in five function group (item 1 to 5). The control function (B) is the central part of the fire detection and alarm system. It monitors different alarm input from automation fire detection device (A) such as flame detectors, smoke detectors, ... and manual initiating device (D) such as pull stations, call points, …, and then trigger alarm output devices like loudspeakers, warning lights, ringing bells, … (item C and M). The control panel also controls fire protection system or equipment, which is fire/smoke doors, smoke and heat control system, sprinkler, … (item G and H). It also responsible to check for faults in the system (item J and K) manage the ancillary equipment, for example cabinet, fire extinguishers, hose reel, … (item N and O) and maintain the connection of fire detection and alarm components (item E and F). The system is powered by power supply equipment (L).

4.2.2 Control and indicating equipment

TCVN 7568-2 also presented that the c.i.e. should be capable of indicating these following functional conditions:

- Quiescent condition;
- Fire alarm condition;
- Supervisory signal condition;
- Fault warning condition;
- Disablement condition;
- Test condition;

The c.i.e. should be able to indicate any combinations of all the above functional conditions at the same time except quiescent condition. Also, any kinds of information shall be capable to be displayed during the quiescent condition. Nevertheless, no indications shall be confused with indications used in other conditions.

Next, the general principle and requirements of all other conditions are stated in TCVN 7568-2. Firstly, the c.i.e. should be in the fire alarm condition when signals that are received considered as a fire alarm. The c.i.e. must be able to receive, handle and show signals from zones, and the signal from one zone shall not interrupt the process of signal from other zones. Lastly, the c.i.e. shall enter the fire alarm condition within ten seconds after receiving the alarms or the activation of any manual call point.

The second condition is the fault warning condition. The c.i.e. shall be in this condition within 100 seconds of the instance of the fault or the reception of a signal, which after checking, is considered as a fault.

The third condition is the disablement condition. Disablement of each zone should prevent all corresponding main indications/outputs or both from that zone, but should not inhibit other main indications and/or outputs from other unaffected zones. And the disablement and re-enablement must not be disturbed by a reset from the fire alarm condition or the fault warning condition.

The test condition is one of the remaining two conditions. The c.i.e. would enter test condition when one or more zones are under test. It must be able to test each zone individually. Zones that are testing should not hinder the main indications and outputs from zones that not under tests. And only a manual operation can make a test state entered and cancelled.

The last condition is supervisory condition. The c.i.e. would be in this condition within 100 seconds of the occurrence of the signal, which after necessary processing viewed as an abnormal status (other than a fault) of devices supervised by the c.i.e. that could affect the operation of other system being watched by the c.i.e. (TCVN 7568-2, 2013)

Another important aspect that mentioned in TCVN 7568-2 is how the data are indicated and indications ‘s requirements in the c.i.e. The first means of indications is light-emitting indicators. Main indications from light-emitting indicators must be visible in an ambient light intensity up to 500 lux, at any angle up to 22.5 degrees from a line through the indicator perpendicular to its mounting surface at 3 m distance for the general indications of function condition and the supply of power, or at 0.8 m distance for other indications.

The data can also display on the c.i.e. by means of alphanumeric number. Main indication shall be legible for the lesser of 1 h or the duration of the standby power source, following the display of a new indication of fire or fault, at 0.8 m distance, in ambient light intensities from 5 lux to 500 lux, at any angle from the normal to the plane of the display up to 22.5° when viewed from each side and 15° when viewed from above and below.

The light-emitting indicators have colour requirement such as: red for indications of fire alarm, fire alarm routing equipment signals, automation fire protection equipment signals; yellow for indication of fault warning, disablements, zones in the test state, fault warning routing system signals and delays to outputs; green for the indication that the c.i.e. is supplied with power. The alphanumeric displays do not have to use different colours, however, if they do, the colours used would be same as stated above.

Finally, the audible indicators are also a part of the c.i.e. They can be used for fire alarm and fault warning indications. The minimum sound level at a distance of 1 meter with any access door on the c.i.e. closed would be either 60 dB for fire alarm indications and 50 dB for fault warning indications or 85 dB for fire alarm indications and 70 dB for fault warning indications. (TCVN 7568-2, 2013).

4.2.3 Power supply unit

TCVN 7568-4 showed the general requirement of the p.s.e. that there should be at least two power sources for the power supply of the system: the main and the standby power source. The main power source must be made to work from the public electricity supply or similar system. When the main source is active, it shall be the only source of power to the fire detection and alarm system, except for currents connected to battery monitoring. if the primary power source fail, the p.s.e. must be automatically switched over to a standby power source, when the primary power source is repaired, it shall be automatically switched back. Where a battery is operated, the p.s.e. must have the charging equipment to charge the battery and sustain it in a fully charged state. Finally, when one of the power sources is failed, it shall not cause the loss of any other power source or fail to supply power to the system.

The main power source’s functions are it helps the p.s.e. operates according to its specifications given by the manufacturer, unconcerned about the status of the standby power source. When using the primary source, the p.s.e. should be able to provide power and charge the battery at the same time. Finally, it can limit or cut off the battery charging when it is delivering a short duration maximum output load.

The functions of the standby power source are pretty identical to the primary power source. The standby source must be able to operate without regard to the condition of the primary source. Also, the standby source contains a battery should be rechargeable, fitting to be maintained in a fully charged state, assembled for stationary use, marked with type designation and date of manufacture and have a safety mechanism to prevent explosion.

Finally, the p.s.e. must be able to identify and give a warning within 100 seconds of the occurrence of these faults: loss of power voltage of the main power source, failure of the standby power source, loss of the battery voltage, loss of the battery charger. (TCVN 7568-4, 2003).

4.2.4 Point heat detectors

TCVN 7568-5 presents that the heat detectors must follow one or more of these classes: A1, A2, B, C, D, E, F, or G depending on the alarm temperature and surrounding operating temperature. Each detector class has a static response and possibly have a rate of rise response. Manufacturers may optionally give additional information regarding the type of heat detector by adding the suffix S or R to the below classes. The affix R means that the detector has been examined and approved as a rate-of-rise detector, while the affix S means that the detector tested and accepted as a static detector. (Apollo-fire, n.d.). Table 2 shows the point heat detector classes temperature requirements.

Table 2. Detector classification temperatures (TCVN 7568-5, 2013)

Detector class	Typical Application Temperature °C	Maximum Application Temperature °C	Minimum Static Response Temperature °C	Maximum Static Response Temperature °C
A1	25	50	54	65
A2	25	50	54	70
B	40	65	69	85
C	55	80	84	100
D	70	95	99	115
E	85	110	114	130
F	100	125	129	145
G	115	140	144	160

The general requirements the heat detector introduced in TCVN 7568-5 are each detector shall be constructed such that at least part of its heat sensitive element(s), except elements with auxiliary functions, shall be ≥ 15 mm from the mounting surface of the detector. Class A1, A2, B, C or D detectors shall be provided with an integral red visual indicator, by which the individual detector which released an alarm, may be identified, until the alarm condition is reset. Where other conditions of the detector may be visually indicated, they shall be clearly distinguishable from the alarm indication, except when the detector is switched into a service mode. Class E, F or G detectors shall be provided with either an integral red indicator, or with another means for locally indicating the alarm status of the detector. The visual indicator shall be visible from a distance of 6 m at an angle of up to 5° from the axis of the detector in any direction or 45° from the axis of the detector in at least one direction, in ambient light intensity up to 500 lux. (TCVN 7568-5, 2013).

4.2.5 Carbon monoxide fire detectors

TCVN 7568-6 introduces that CO fire detectors can react immediately to slow, smouldering fires involving carbonaceous materials because CO does not depend only on convection, but also moves by diffusion, and they can be better fitted for applications where other fire detection methods are prone to false alarms, i.e. due to dust, steam and cooking vapours. It is essential that the location of CO fire detectors considers areas where false operation or nonoperation is likely. CO fire detectors might not be suitable for detecting fires involving

- Non-carbonaceous materials,
- Clean-burning liquids,
- PVC-insulated cables,
- Combustible metals,
- Certain self-oxidizing chemicals.

Some common locations where it need evaluate carefully the use of CO fire detectors are areas where CO gas can be cause from vehicles 's exhausts and normal manufacturing processes. Examples: Car parks, car-park return air plenums, loading docks. (TCVN 7568-6, 2013)

The main requirements of CO fire detectors presented in Vietnam standard are: Each detector shall be given an integral red visual indicator, by which the individual detector that released an alarm can be distinguished, until the alarm condition is reset. Where other conditions of the detector can be visually indicated, these shall be clearly discernible from the alarm indication, with the exception of when the detector is changed into a service mode. The visual indicator shall be visible from a distance of 6 m at an angle of up to 5° from the axis of the detector in any direction or 45° from the axis of the detector in at least one direction, in ambient light intensity up to 500 lux. (TCVN 7568-6, 2013).

4.3 Comparison of the fire detection and alarm system standards between Finland and Vietnam

As mentioned at the beginning in chapter 4.2, the Vietnam standard for the fire detection and alarm system contains five parts, therefore, the author has compared these five parts with their counterparts in the Finnish standard.

4.3.1 General

On the one hand, the author recognized the Vietnam standard and the Finnish standard share some similarities. Firstly, the functions of fire detection and alarm system are basically identical to each other in both standards. And secondly, when the author compared figure 1 and 2, despite the difference, which is in the Vietnam standard, there are more function groups, five to four in the Finnish standard (control and indication functional group). The general principle of the fire detection and alarm system in both standards is the same as each other.

On the other hand, there is notable difference in both standards. Comparing to Finnish standard, Vietnam standard has more requirements of the system. These addition requirements are showed in the second paragraph of section 4.1.1. That is also the only contrast the author can find.

4.3.2 Control and indicating equipment

When compared all things stated above from the Finnish standard to the Vietnam standard, the author saw there are a few minor differences. Firstly, the Vietnam standard presented that the c.i.e. has one more condition, which is the supervisory signal condition, than its counterpart in Finnish standard. In the audible indicator parts (the last paragraph of chapter 4.1.2 and 4.2.2). It presents additional sound level, which is 85 dB for fire alarm indications and 70 dB for fault warning indications. The reason as stated in the standard is the allowance for two sets of audible indications contemplates some c.i.e. being installed in normally occupied areas (such as a security room).

On the other hand, all other parts in both standards are similar to each other.

4.3.3 Power supply unit

After compared both standards, the author found that for the most part, the Vietnam standard shared the similarities to the Finnish standard. But there is a distinction in the last paragraph of both chapter 4.1.3 and 4.2.3. In the Vietnam standard, it is stated that the p.s.e. needs to recognize and signal the faults with 100 s of the occurrence of all the fault presented above, while in the Finnish standard, the time are 30 minutes or 15 minutes. This is the only difference the author saw after comparison.

4.3.4 Point heat detectors

After analysed both standards, the author concluded that Vietnam standard shared resemblance about point-type heat detector to its counterpart.

4.3.5 Carbon monoxide fire detectors

When compared about the general idea and definition of CO fire detectors (the first paragraph of chapter 4.1.5 and 4.2.5), the author found that Vietnam standard goes further into the condition when setup the CO fire detectors such as where you should test before install them and which fire involve in which material that CO fire detectors are not suitable to be used. Then, for the requirements of CO fire detectors, the Vietnam standard is a bit different than the Finnish standard. The difference is the angle where you can see the visual indicator of the CO fire detector. It is 5° from the axis of the detector in any direction or 45° from the axis of the detector in at least one direction in the Vietnam standard and directly below the detector in the Finnish standard.

4.4 Fire detection and alarm system in buildings and constructions in Vietnam and Finland

Here is some information about the fire detection and alarm system in buildings and constructions in Vietnam and Finland

4.4.1 In Finland

In Finland, the list of buildings needs to have fire alarm system are:

- Dwellings, for example: residential apartments, leisure apartments;
- Accommodation premises, for example: hotels, holiday homes, residential homes;
- Institutions, for example: hospitals, old people’s homes, prisons;
- Assembly and business premises, for example: restaurants, shops, schools, sport halls, churches, …;
- Office premises, for example: offices, bureaus, administrative premises;
- Production and storage premises, for example: ordinary industrial premises, premises for agricultural production, large warehouses;
- Garages.

(Act on Decree of Ministry of the Environment on fire safety of building, 2002).

4.4.2 In Vietnam

In Vietnam the types of building and construction must have automatic fire alarm system installed are described more specifically:

- Administrative building, office facilities from the 5th storey and above
- Accommodation facilities with 5 floors and above;
- Schools, science organizations and designs, management authorities (high school, university, colleges, …)
- Public cultural and sport works with design from 200 seats and above; or with area from 200m2 and above;
- Airports; first grade railway station (station for goods and passengers); houses for parking cars and motorcycles;
- Production houses, production constructions with flammable substances, goods;
- Power plants, indoor transformer stations; storages, ports for export and import petroleum, liquefied petroleum gas;
- Center of command, moderation, operation, control scale of area and nation belongs to fields;
- Security, national defense constructions with danger of fire, explosion or special protection requirements;
- Underground constructions with fire hazard, explosion, basement.

(TCVN 3890:2009, 2009).

4.4.3 Analysis between two countries

As the author saw, the types of buildings and constructions that are required to have a fire alarm system is a bit different in Vietnam and Finland. In Finland, by law all residence must have a functioning fire alarm system. While in Vietnam, except accommodation facilities below five floors and public cultural and sport works facilities with less than 200 seats, or with area less than 200 m2, all other kinds of facilities, premises must have a working fire alarm system. This also means normal residence house, or small public places in Vietnam does not require to have a system.

4.5 **Conclusion**

After doing the comparison, the author concluded that for the most part, the Vietnam standard and the Finnish standard is identical to each other, and there are no major differences in technical aspect. The differences of two standards are explained detailed in section 4.3.

In chapter 4.4, the author has pointed out the contrasts between Vietnam and Finland in the fire alarm system in buildings and constructions. The main difference is in Vietnam, normal residence houses that have less than five floors is not requires to have the fire alarm system installed. That is the main reason for the author to come up with the practical part.

5 FIRE ALARM SYSTEM USING ARDUINO AND OTHER COMPONENTS

5.1 Overview

The thesis practical part's target is to create a fire alarm system using an Arduino UNO board and other parts. As stated in chapter 4, in Vietnam, normal residence houses do not require bylaws to have a fire alarm system installed, while in Finland, by Finnish law every residence must have a functioning fire alarm system. Furthermore, according to Statista website, in 2014, 97% Finnish households have a fire alarm system. (Statista, n.d.) Therefore, the author has made fire alarm system using Arduino Uno based on Vietnam situations.

As mentioned earlier in chapter 4, a fire alarm system has four main elements: control and indicating equipment, power supply unit, point heat detector and carbon monoxide detector. For that reason, the author used components that represent a real-life system. There are:
- Control unit: Arduino Uno.
- Control panel: 3x4 keypad and a combination of 16x2 Liquid Crystal Display (LCD) and I2C module.
- Smoke sensor: MQ-2 gas/smoke sensor.
- Flame sensor: IR Flame Sensor
- Alarm: Led and buzzer.
- Wireless control and communication: GSM SIM900 shield.

5.2 Control unit – Arduino Uno

5.2.1 Introduction

Arduino is an open-source electronics platform which good for developing electronics projects based on easy-to-use hardware and software. It comprises of a physical programmable circuit board (often referred as a microcontroller) and a piece of software, or IDE (Integrated Development Environment) that runs on the computer, which is used to write and upload computer code to the physical board. The Arduino platform has become well-known for people who just beginning with electronics, with many advantages. Unlike most previous programmable circuit boards, the Arduino does not require a separate piece of equipment (called a programmer) to upload the new code onto a board, for that purpose we can simply use a USB cable. Moreover, its IDE uses a simplified version of C++, making it simpler to learn to program. Lastly, Arduino gives a standard form factor that helps the microcontroller becoming more accessible. (Sparkfun, n.d.) Arduino makes several different boards with different abilities like Arduino Uno (R3), Lilypad Arduino, Arduino Mega 2560, Arduino Yún, …

Because its flexible, easy to use and low-cost nature, in this project, an Arduino Uno was used.

5.2.2 Arduino Uno

The characteristics of the Arduino Uno are shown in figure 8. According to the Arduino website, Arduino Uno is a microcontroller board based on the ATmega328P. It can operate on the external supply of 6 – 20 volts, but the recommended range is from 7 to 12 volts (if the board is supplied less than 7 volts, the 5V pin may deliver less than 5 volts, it would not be stable to use, and if using more than 12V may cause the board to overheat and damaged). It has 14 digital input/output pins that can operate at 5 volts; 6 analog inputs labeled from A0 to A5. A 16 MHz quartz crystal, a USB connection, a power jack, an ICSP header, and a reset button. It contains everything needed for the microcontroller to work; just connect the Arduino board to a computer with a USB cable or supply its power through an AC-to-DC adapter or connect to the battery to get started. (Arduino, n.d.)

In this project, Arduino Uno is power supplied by connecting to a PC with a USB cable.

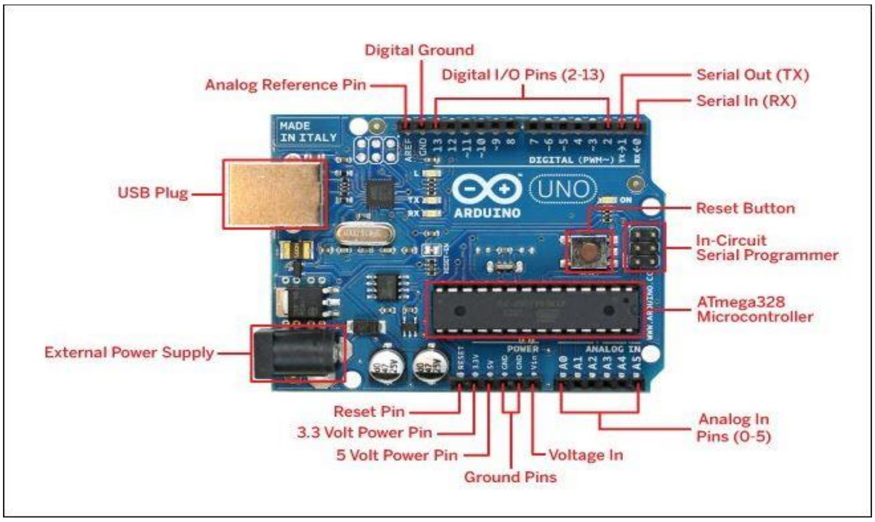


Figure 8. Arduino Uno characteristics (robu, n.d.)

5.2.3 Arduino software (IDE)

In order to write and compile the code to the Arduino boards, Arduino Integrated Development Environment (IDE) is used. Arduino IDE is an open source and official Arduino software, which make programming code easier, even for people who have no prior knowledge. It is available in operating systems such as MAC, Windows, Linux. The IDE generally consists of two basic parts: Editor and Compiler. The former is used for writing the code and the latter is used for compiling and uploading the code into the Arduino boards, in this case, it is the Arduino Uno. The IDE supports both C and C++ language.

When we start the IDE, a window like figure 9 will appear. The figure marks with information about Arduino IDE for more understanding. The detailed explanations are given below.

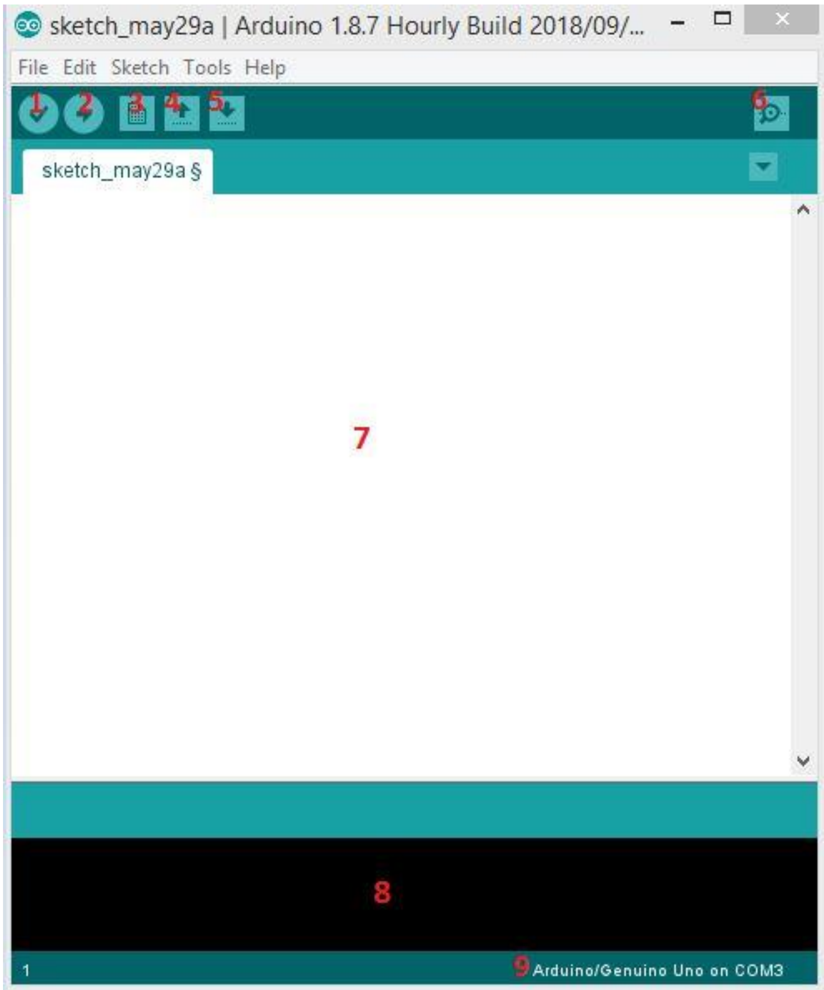


Figure 9. Arduino IDE interface characteristics

- 1: Verify - compiles and verify the code in the sketch.
- 2: Upload - upload the code to Arduino module.
- 3: New Tab - opens a new sketch window.
- 4: Open - open any existing sketch.
- 5: Save - save current sketch.
- 6: Serial Monitor - opens a window to send and receive information from Arduino module.
- 7: An area for writing the code
- 8: Console - show details of errors and warnings, useful for debugging.
- 9: Board & Serial Port Selections - show which kind of the Arduino board and what serial port are ran. In this case, the Arduino Uno and port COM3 was used.

(STEMTera, n.d.)

Furthermore, the Menu bar is on the top of the interface, which has five different options as follows:

- File: Create a new window for writing the code or open an existing one.
- Edit: Has font modification for the code, as well as copy and paste function.
- Sketch: For compiling and programming, include the new libraries for Arduino if needed.
- Tools: Used for testing projects, shows which Arduino boards and port are in used.
- Help: Have getting started and troubleshooting part to help with the software.

(theengineerproject, n.d.)

5.3 Control panel

In this project, the control panel comprises the combination of 16x2 LCD with I2C module and 3x4 keypad.

5.3.1 16x2 LCD

Liquid Crystal Display, abbreviated LCD, is a display module technology that generally used in TVs, monitors, tablets, and smartphones, ... The LCD has several advantages over other kinds of the monitor such as low cost, simple to program, good for brightly lit environments, use little electricity and generate little heat.

16x2 LCD means the LCD can display two lines, each line can have sixteen characters. It has two registers, which is Command and Data. The command register saves the command instructions provided to the LCD, for example: initializing the LCD, set the cursor position, … The data register saves the info to be displayed on screen. Figure 10 shows the images of 16x2 LCD screen characteristics.

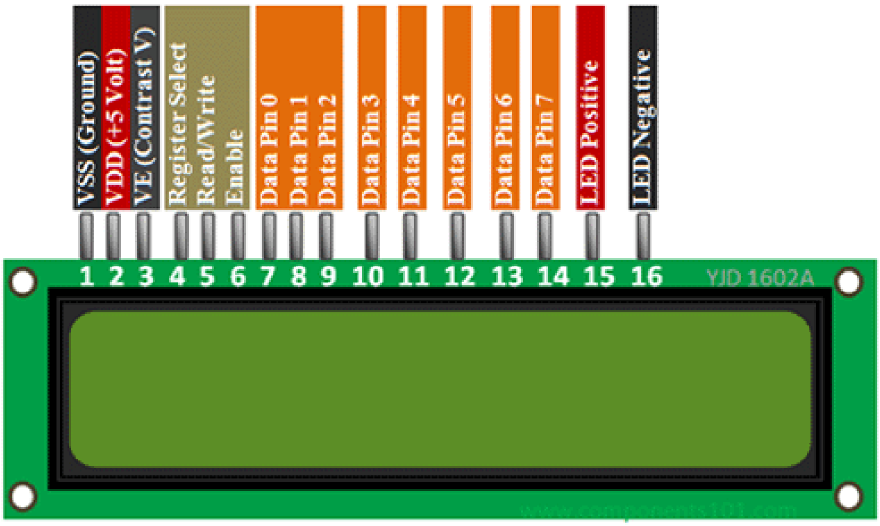


Figure 10. 16x2 LCD screen characteristics (components101, n.d.)

The 16x2 LCD has total 16 pins, there are (from left to right):

- VSS (Ground): ground pin to connect the system ground
- Vdd (+5 Volt): supply voltage (4.7V – 5.3V).
- VE: adjust the contrast level.
- Register Select (RS): selects between the command and data register.
- Read/Write: used to read or write the data.
- Enable: control the data send to data pin.
- Data pin 0 – 7: 8 bits data pins.
- LED + and LED -: backlight LED power supply.

(16x2 LCD datasheet, 2008).

Figure 11 shows the LCD used in this project.

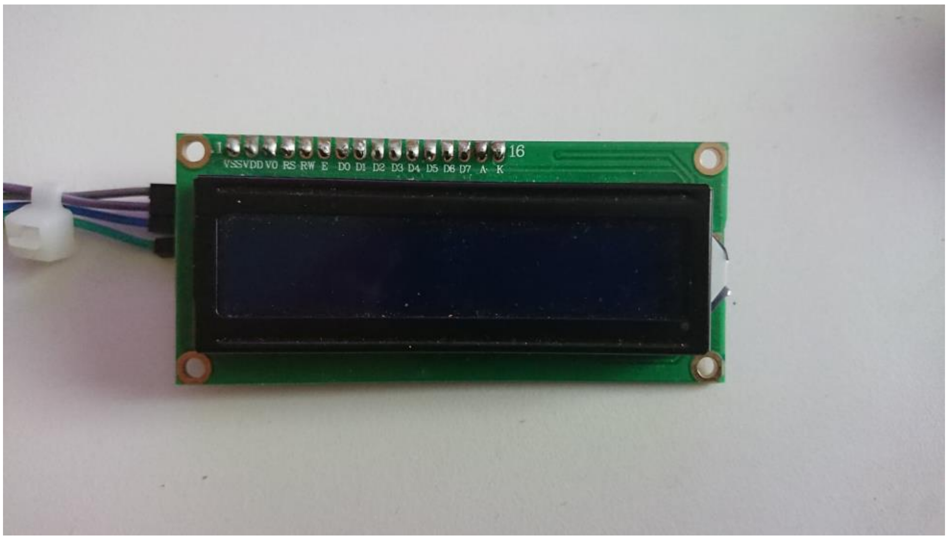


Figure 11. 16x2 LCD screen

5.3.2 I2C module with 16x2 LCD screen

The Inter-integrated Circuit communication protocol, abbreviated I2C, is a serial protocol aimed for permit multiple “slave” digital integrated circuits (“chips”) to communicate with at least one “master” chip. Like the Serial Peripheral Interface (SPI), it is designed only for short distance communication within a single device. And like Asynchronous Serial Interfaces (such as RS-232 or UARTs), it just needs two signal wires to exchange data which call SDA and SCL. (Sparkfun, n.d.)

Figure 12 shows what an I2C look like.

Figure 12. I2C module (botshop, n.d.)

To use the I2C module with 16x2 LCD, user can make a connection between those two using a breadboard or by solder them together. The main advantage of having this kind of LCD is the LCD only needs two analog pins on the Arduino (which is pin A4 and A5 on an Uno), compare to using up to sixteen pins normally. There is a dedicated Arduino library of I2C LCD helps to program it easier.

Figure 13 shows LCD with I2C utilized in this project.

Figure 13. 16x2 LCD with I2C module

5.3.3 3x4 keypad

A 3x4 keypad is used as an input device and communicates with Arduino for this project. It is a numeric matrix keypad with 12 keys. The I/O pins of the keypad are wired as 3 columns by 4 rows. The Arduino boards can detect which key is pushed because when that action happens, it creates a closed circuit, allow the current flow between a specific column and row pins and the Arduino can detect that.

Figure 14 shows a 3x4 keypad is used in the project.

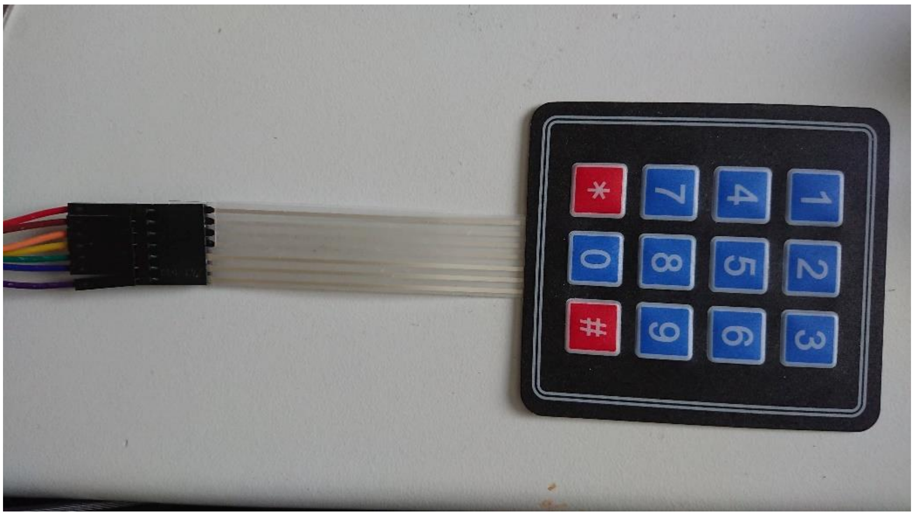


Figure 14. 3x4 keypad

5.4 **Smoke sensor and flame sensor**

A normal fire alarm system usually has a smoke detector or a point heat detector. In this project, the author used an MQ-2 gas sensor as a smoke detector and IR flame sensor. The reason a temperature sensor was not used is after some testing, the author found they did not work stably so the IR flame sensor was used instead.

The MQ-2 gas sensor can detect most noticeably LPG (natural gas) and smoke (carbon monoxide) so it is very is useful for gas leakage or smoke detection. Because of its high sensitivity and quick response time, a measurement can be taken as quickly as viable. The sensitivity of the sensor can be tuned via the potentiometer below the gas sensor module. Figure 15 shows the MQ-2 sensor used in the project.

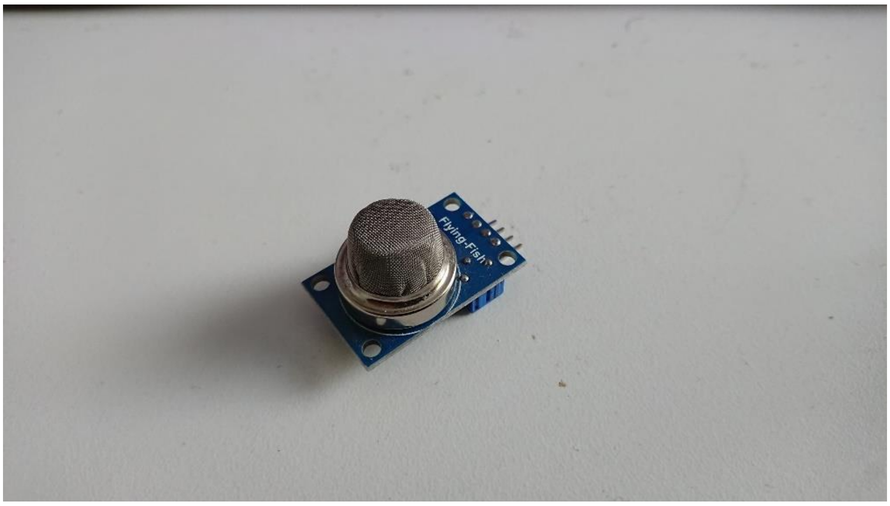


Figure 15. MQ-2 gas sensor

A fire sensor module contains a fire sensor (IR receiver), resistor, capacitor, potentiometer at the bottom, and comparator LM393 as an integrated circuit. It can recognize infrared light with a wavelength running from 700nm to 1000nm. The fire probe converts the light detected distinguished as infrared light into the current changes. Sensitivity is tuned via the on-board resistor with a detection angle of 60 degrees. (pcboard, n.d.).

Figure 16 shows the IR flame sensor used in this project.

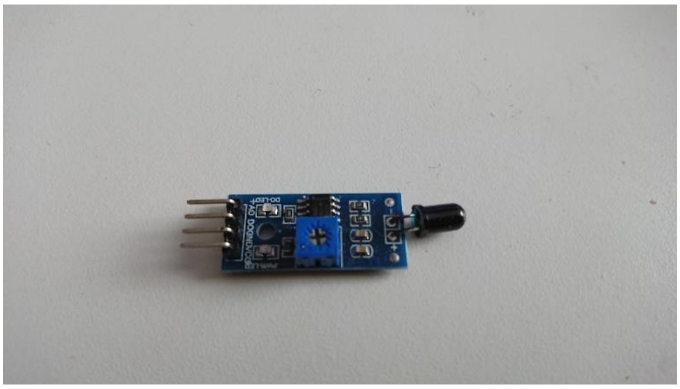


Figure 16. IR flame sensor

5.5 LED and Buzzer

For the demonstration purpose, an LED and an electromagnetic buzzer were used in this project as an alarm and warning method. To be more effective in real life situation, an alarm light and a high voltage alarm can be used with relay module. Figure 17 and 18 show the buzzer and the LED used in this project respectively.

Figure 17. A Buzzer

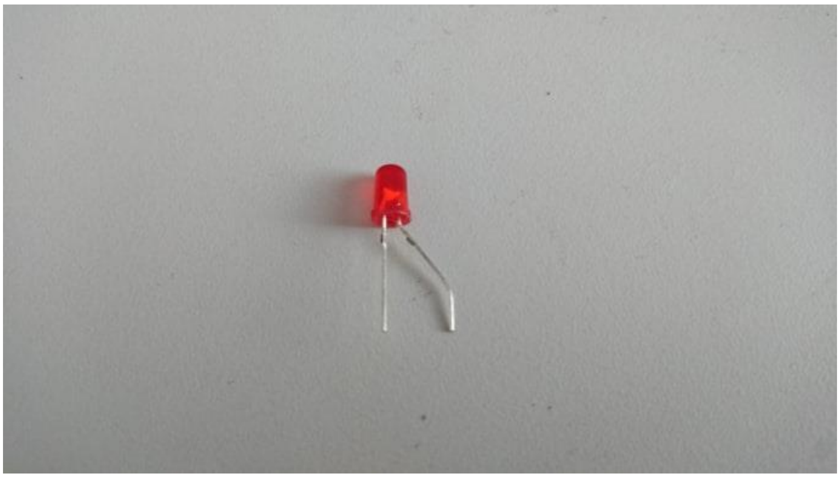


Figure 18. An LED

5.6 Wireless control – Sim 900 shield

For the system can be controlled wirelessly like almost everything nowadays, a SIM 900 GSM/GPRS (stands for Global System for Mobile Communications/ General Packet Radio Service) shield is used.

SIM900 shield is a complete Quad-band GSM/GPRS module in a Surface-mount technology (SMT) module. It can work with 5V power supply and compatible with any Arduino boards. It allows user to send SMS, GPRS, making phone calls via UART (Universal asynchronous receiver-transmitter) communication using AT commands or customized Arduino library. SIM900 provides GSM/GPRS system with frequencies of 800/900/1800/1900 MHz, so it can work in all countries with 2G networks. (randomnerdtutorial, n.d.) With its small size, low power consumption and excellent wireless control solution make SIM900 shield a suitable component for this project. Figure 19 shows the SIM900 shield used in this project.

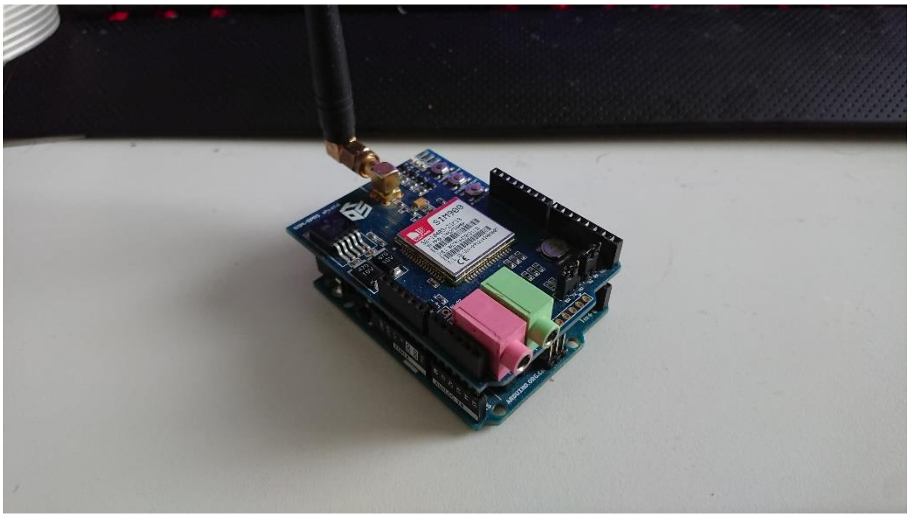


Figure 19. SIM900 shield stack with the Arduino Uno

6 FIRE DETECTION AND ALRAM SYSTEM IN OPERATION

6.1 System setup

Figure 20 shows the connection between the Arduino Uno and the 3x4 keypad.

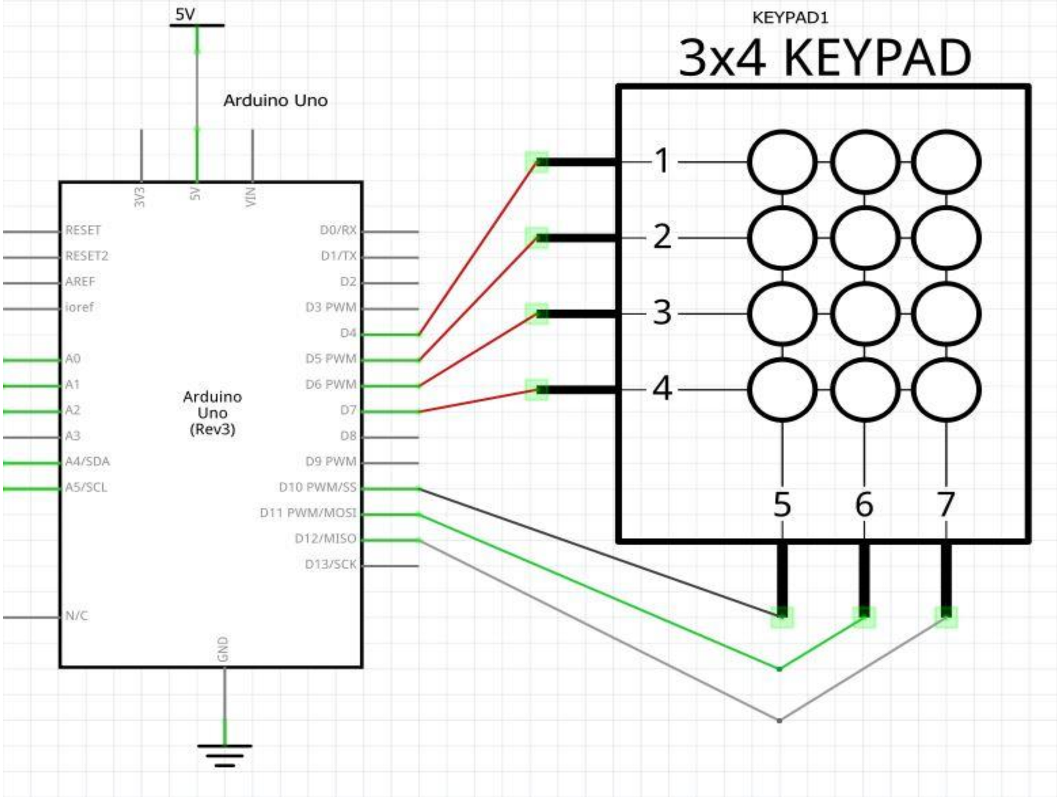


Figure 20. The Arduino Uno and 3x4 keypad circuit diagram

Figure 21 shows the connection between the Arduino Uno and the sensors, the buzzer, the LED and the 16x2 LCD screen with I2C module.

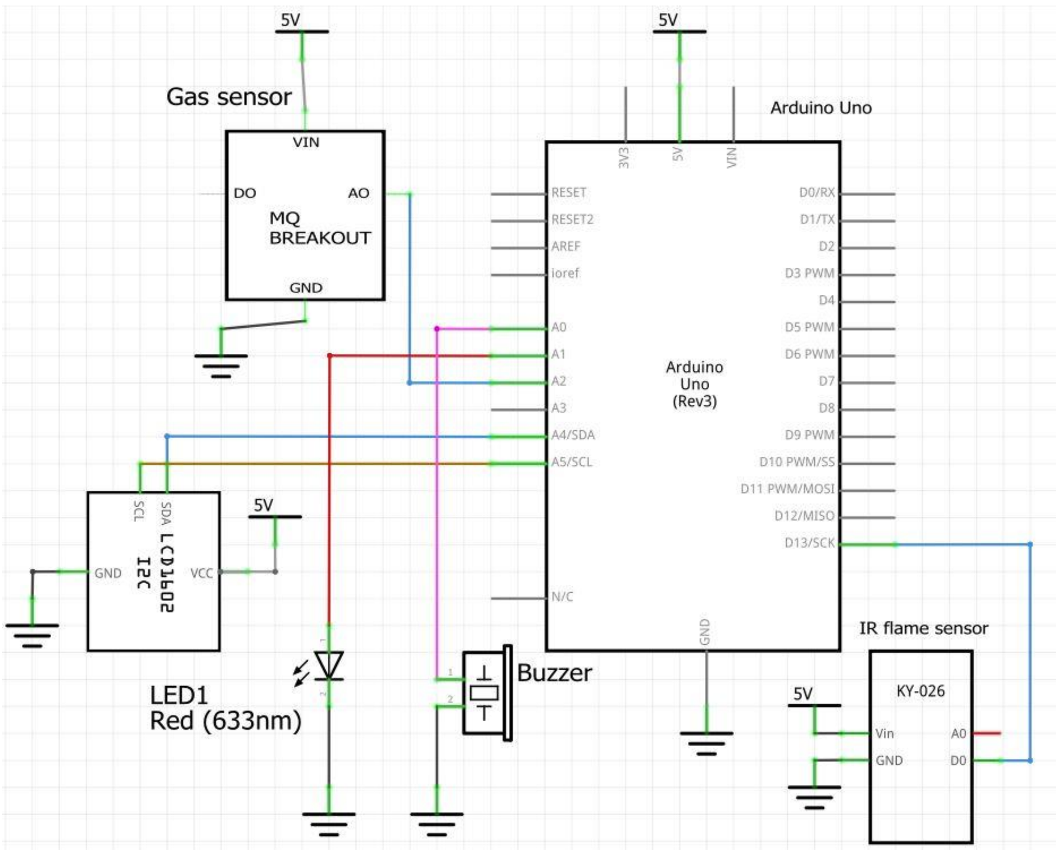


Figure 21. The Arduino Uno with sensors, LED, buzzer and LCD screen

Noted that in this project, the SIM900 shield is stacked above the Arduino board, but figure 22 shows the important pins connection between the SIM900 shield and the Uno.

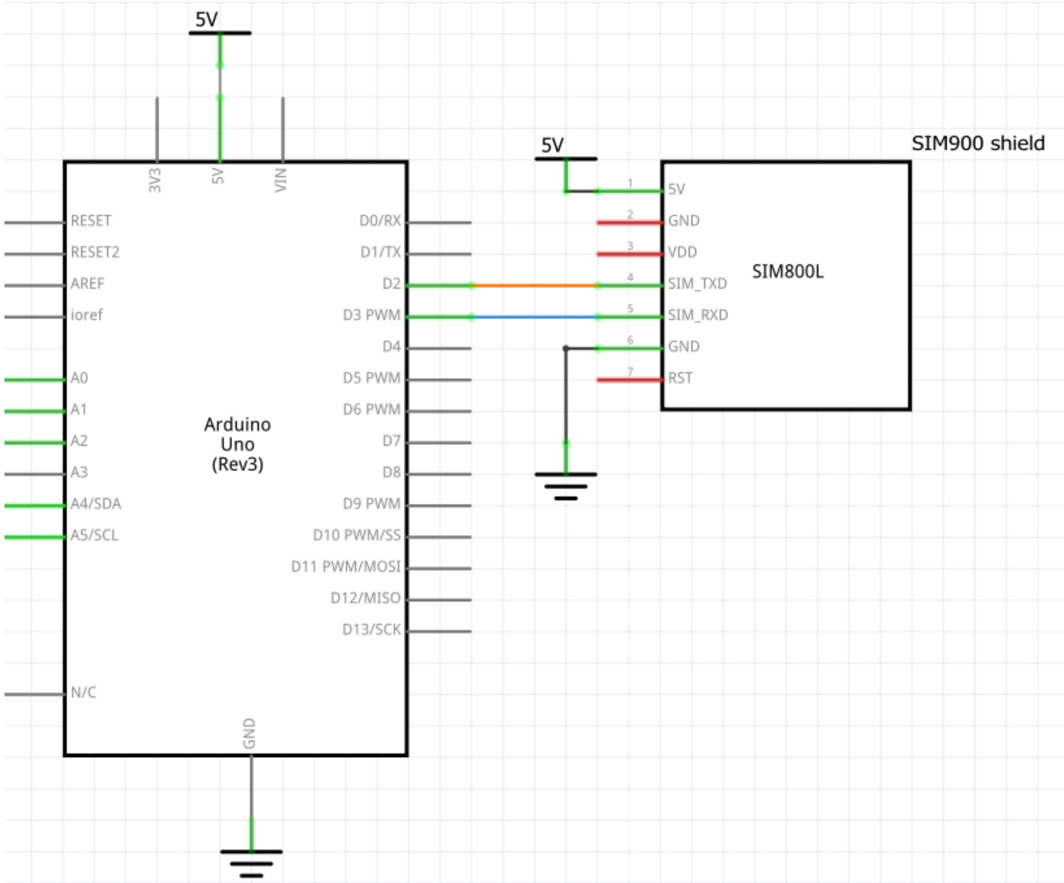


Figure 22. The Arduino Uno with SIM900 shield

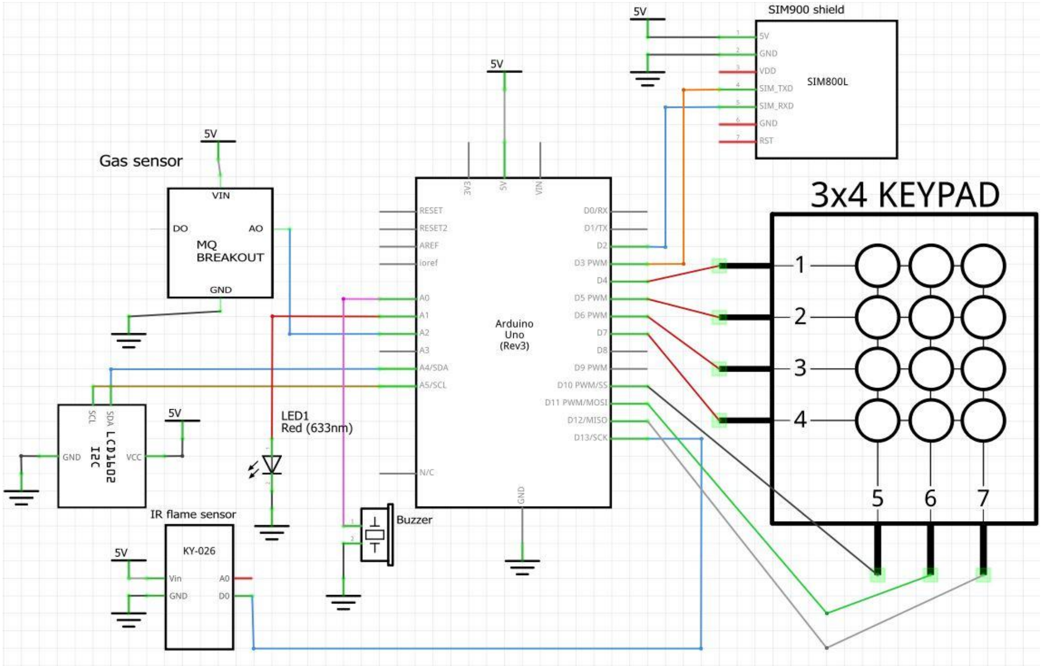


Figure 23. The fire alarm system circuit diagram

Finally, figure 23 shows the overview circuit diagram of the fire alarm system, with all other components connection with the Arduino Uno. The figure can be zoomed in for better viewing.

In real life application, at the present, the fire alarm system works best in an apartment. In Vietnam, there is no regulation about the position of the smoke sensor, while in Finland, there is a regulation about it. According to Tukes website, for each 60m2 of each floor of a residence house, there must be one smoke alarm installed at the minimum. Also, it is recommended to have one smoke alarm for each bedroom and hallway lead to it, the smoke alarm should be installed on the ceiling in the middle of the room and not closer than 50 cm to a wall, corner or rafter. (Finnish Safety and Chemicals Agency, n.d.). And there is no regulation for the flame sensor. Therefore, this setup is based on Finnish regulation and also after the author observed some other fire alarm system. Because the MQ-2 sensor is the versatile detector, which can detect gas or smoke, it can be installed either in the kitchen, where the natural gas is stored and used most in case of a gas leakage (at least in Vietnam), or in the bedroom and in the hallway that lead to bedroom(s) in case of the smoke set off. The smoke sensor should be installed in the ceiling and there should not be anything block the sensor. The flame sensor can be set near the main electric control box, where a fire may likely occur. The control panel can be put in a small junction box and installed in easy-to-access places, recommend near a main door, in a living room or in a bedroom.

6.2 System control

When the system first start, it will be in the default state.

- Default state: When the system is in a default state, the LCD is turned off. Owners must press '*' in the keypad to turn on the LCD. At this time, the menu screen with numbers and abbreviations of matching options will appear. Owners can choose these options by their corresponding keypad, which are:
  - Key 1: Home mode 1.
  - Key 2: Home mode 2.
  - Key 3: Away mode.
  - Key 4: Turn off mode.
  - Key 5: Shows the last five numbers of predetermined phone numbers and their slots.
  - Key #: Turn off the LCD.
  - Key *: Return to menu screen or turn on the LCD.

  The details of all above modes are explained carefully in chapter 6.3. After a few seconds of inactivity, the screen will turn off, the owners must press '*' to return to the select menu again.

- Alarm state: when the system enters the alarm state, owners must use a keypad or call the system using predetermined numbers to stop the alarms and reset the system.

- Wireless control:
  When the system is in the default state, owners can send SMS messages to the system with authorized phone numbers to set the options, the messages are as follows:
  - Text '1': set the system to option 1 – Home mode 1.
  - Text '2': set the system to option 2 – Home mode 2.
  - Text '3': set the system to option 2 – Away mode.
  - Text '4': set the system to option 3 – Turn off mode.

  When the system is alarmed, owners can only use the call function.

6.3 Fire alarms measurement

There are four modes for owners to use with different setups and two alarm modes. The first alarm mode is when the gas sensor triggered, the system would turn on the led and buzzer to warn owners there may a gas leak threat. The second alarm mode is the fire alarm, when flame sensor set off, with a few first few seconds, the led blink and buzzer turns on. And then, the system calls the first saved phone number. After that, it calls the next saved number, in the meanwhile, the led and buzzer stay on and the keypad is disabled in the process to avoid conflicts. There are two ways to stop the alarms and reset the system. They are:

- Using keypad: Press'*' and enter '4' to set the system to turn off mode. This will be explained more clearly below.

- Calling the system: Owners use saved phone numbers to call the system after the system called their numbers to stop the alarms.

The four modes that can be used are: home mode 1 and 2, away mode and turn off mode.

- Turn off mode: this mode is used to turn off the system, which will deactivate every sensors and alarm. This is also the mode the system will be after reset.
- Home mode 1: Figure 24 below shows how the system works in home mode 1.

  In home mode 1, the system activates the alarm only when the gas sensor set off. When the gas sensor triggered for the first time, the system will turn on the led to warn owners and start the timer. After seven seconds passed, if the sensor is off, the system goes back to default state and the led turns off. And if the inverse situation happens, the system would turn on the buzzer additionally.

  This option fits with households that use natural gas for cooking, power application, and heating fuel.

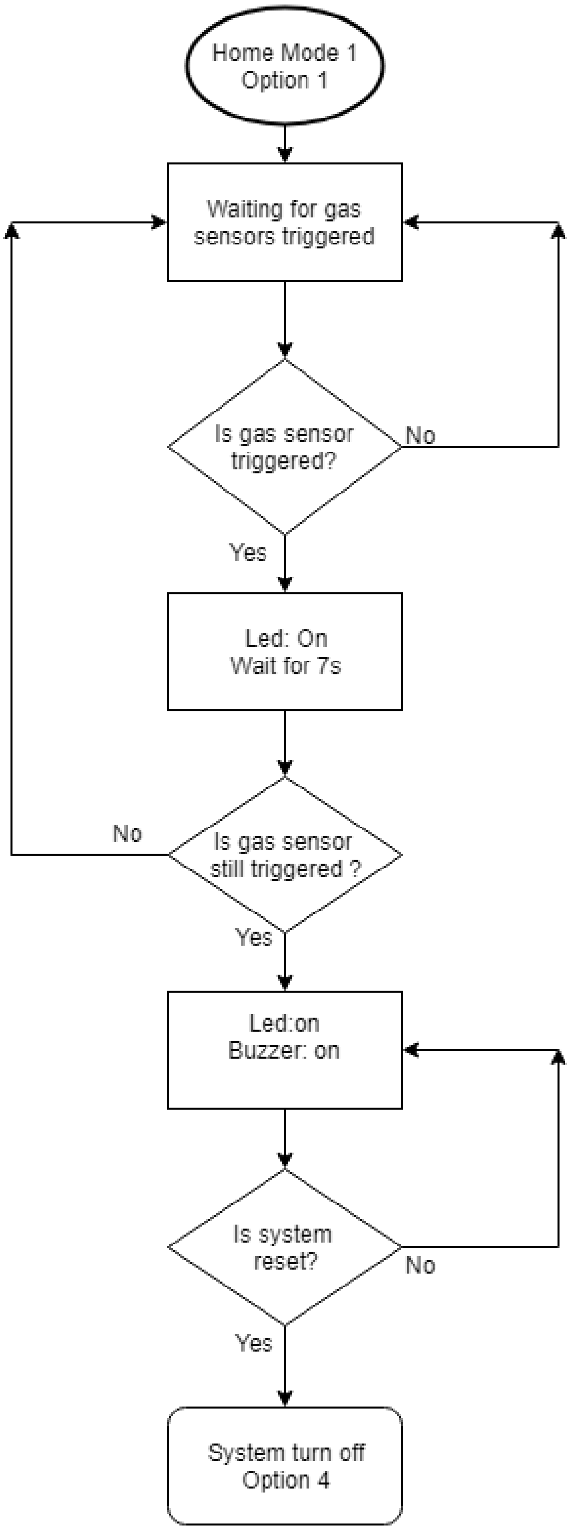


Figure 24. Home mode

- Home mode 2 and away mode: figure 25 shows how the system works in away mode and home mode 2
  Away mode is the best option when there is nobody at homes.
  First, the system is in default state waiting for any sensors to trigger. When any of two sensors set off, the system activates the fire alarm mode. The system turns on the led and buzzer to warn nearby about the threat, while also call owners to report the situations.

Home mode 2 is similar to away mode, but only the flame sensor is actives and the system responds to it exclusively. This mode is suitable when somebody at home and doing the cooking or something that cause smoke.

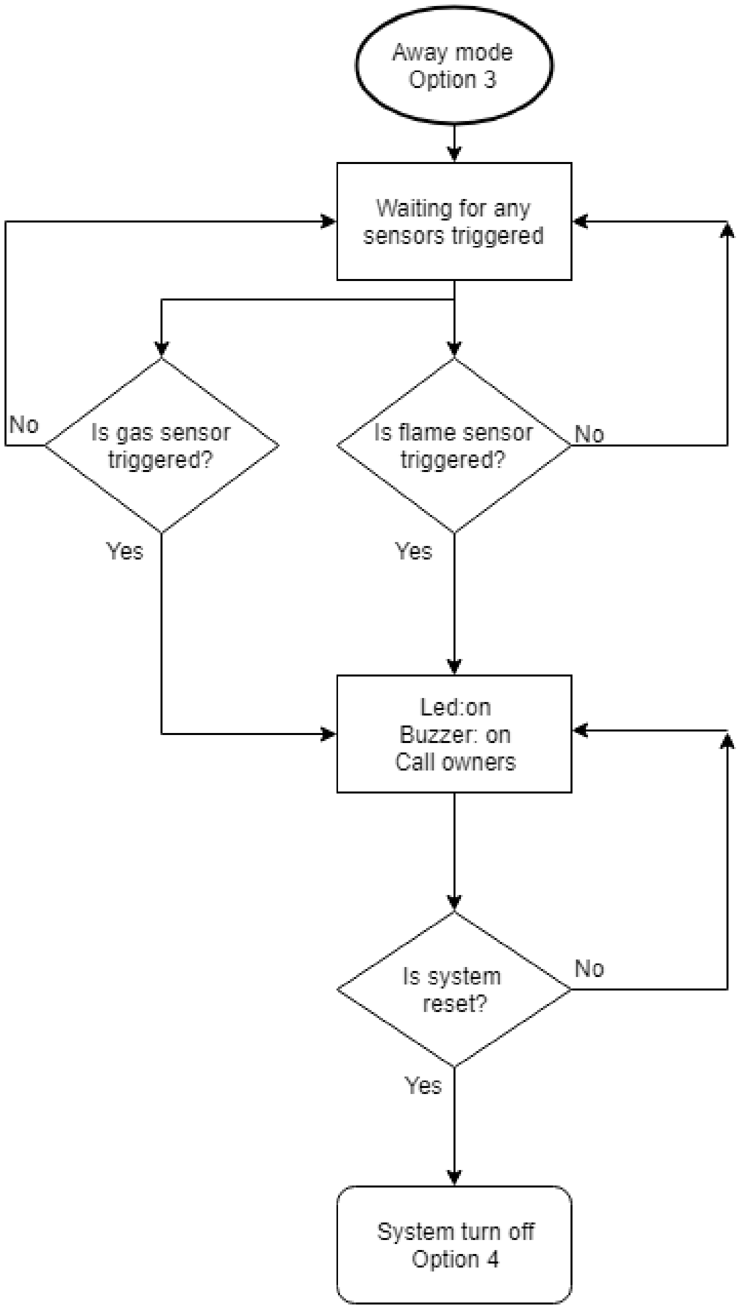


Figure 25. Away mode

7 ANALYSIS OF THE FIRE ALARM SYSTEM USING ARDUINO UNO

After installing the fire alarm system and running some tests, the system was found to work like the author had planned for it to do. The system has distinguished advantages and disadvantages. First of all, the advantages are:

- The installation and maintenance costs are lower compared to common fire alarm systems. According to Safeone Viettel, a common fire alarm system costs around VND 5,400,000.00, which equal to 210 euros in Vietnam (Safeone Viettel, n.d.). While the total cost of the system the author built is around 60 euros.
- The system is easy to install, maintain, replace, and improve.
- Wireless communication can be used without internet.

Secondly the disadvantages are:

- There is no continual monitoring.
- At the moment, the system does not allow to input new phone number directly.
- Because the system is self-implemented so there is no connection to fire department.
- Less monitoring options.
- A short lifespan.
- The wire connection to Arduino can become loose after some time used.

The foremost problem of this system is there is no constant monitoring and no connection to the fire department. To counteract this problem, owners can ask neighbors or nearby acquaintances to keep an eye on the house when the system is triggered. For the phone number problem, the author tried the EEPROM library to provide the ability to input a phone number directly to the system, but this did not work as expected. The problem may be that there are some conflicts between the used Arduino libraries. Therefore, for the present, this option is not present in the system, but the author will try and make it possible later. Even though the fire alarm system using Arduino Uno has fewer monitoring options than a common system, the four modes the author provided are enough to cover most of basic need. The Arduino boards also have their own problems, they have a short lifespan and the pin connection can become loose after sometimes of use. To overcome this issue, owners can replace the Arduino board at a low price and the code can be implemented again easily.

Moreover, some improvements that can be done to the system. Firstly, the battery backup system, right now, the project is powered by connecting to a PC via a USB cable. Therefore, to be able to use in real life situation, the system must have a separate power supply and able to operate even when there is a blackout. So, an Adafruit PowerBoost 500C module and a 3.7V LiIon/LiPoly battery can be utilized. According to Adafruit website, the PowerBoost 500C module has a built-in battery charger circuit, which will keep the project running even while recharging the battery. Furthermore, it can power any 3.7V LiIon/LiPoly battery and convert its output to 5.2V DC for powering the Arduino. By soldering the USB A jack in, users can connect the module to the Arduino board and provide power supply.

When there is a blackout, the battery will provide power for the Arduino project (Adafruit, n.d.). Figure 26 shows the PowerBoost 500C module in operation.

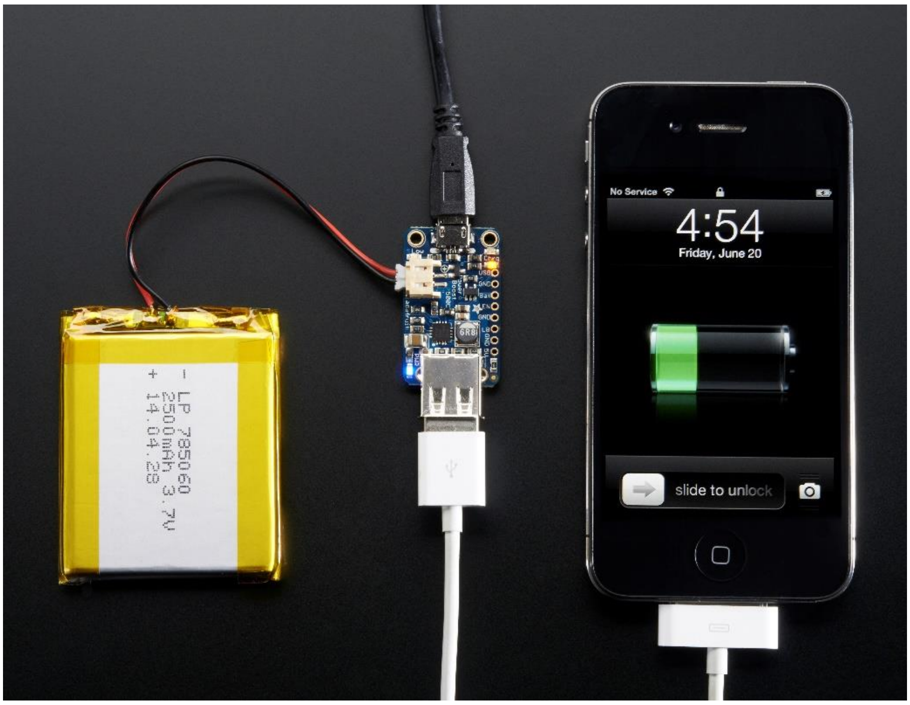


Figure 26. PowerBoost 500C module in operation. (Adafruit, n.d.)

The second improvement that can be made is the ability of having multiple sensors installed wirelessly from the control unit. This improvement helps the system work in a wider environment. By using nRF24L01 transceiver modules combined with Arduino Nano, this improvement can be done. nRF24L01 is a wireless transceiver module that can both send and receive data. It can operate efficiently in a range of one hundred meters and in the frequency of 2.4 GHz, which is legal in almost all countries, thus making it an excellent choice for a wireless solution. The module works at 3.3V hence it can be used with any Arduino boards. Connecting sensors with an Arduino Nano and a nRF24L01 module will help these sensors send data to the control unit, in this case Arduino Uno, wirelessly. Also, a single nRF24L01 can listen up to six other modules simultaneously, hence the fire alarm system can have multiple sensors active at the same time. Figures 27 and 28 show the nRF24L01 module and the Arduino Nano respectively.

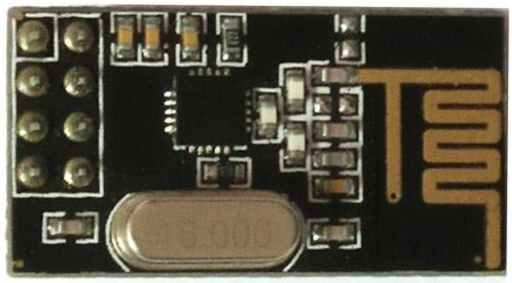


Figure 27. A nRF24L01 module (components101, n.d.)

Figure 28. An Arduino Nano (Arduino, n.d.)

The last improvement that can be done is to create an application that controls the system wirelessly. Some modern fire alarm systems have applications that can not only control the system, but also monitor the status of the system. This improvement would help owners to manage fire alarm system easily from afar.

8 CONCLUSION

After carefully studying and analysing the fire detection and alarm system standards in Vietnam and Finland, the author found that for the most parts, both countries have similar standards and regulations about fire alarm systems in general. However, there are some minor differences that the author has presented in this thesis. They are

In the practical part, a system was developed with Arduino Uno as the main control unit, connected with other devices, such as: a smoke/gas sensor, an IR flame sensor, an LED, a buzzer, a 3x4 matrix keyboard, a 16x2 LCD combine with an I2C module and a SIM900 shield. The sensors monitored constantly, operated fire detectors in a fire alarm system, the LED and buzzer acted as alarms. The system can be controlled through a keypad and an LCD or by a phone call/text through the SIM900 shield. After some tests, the system worked successfully.

Also, the system has distinguished advantages and disadvantages. On the one hand, the advantages are its low cost, easy installation, maintenance, replacement, and improvement the system. With the nature of the SIM900 shield, this system can be used wirelessly in Vietnam or Finland or anywhere else in the world.

On the other hand, the system has some disadvantages. The most notable disadvantage is that the system is not connected to the fire department like a normal system. There are also a few drawbacks about Arduino such as the connection and short lifespan.

Finally, there are some suggestions the author thinks would improve the system, for example:

- Having a separate back-up power system
- Ability to connect multiple sensors wirelessly
- Creating an app as a wireless control method, which would make controlling the system easier in general.

These improvements would make the system more reliable and give it more applications for real life situations.

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Appendix 1

ARDUINO CODE

```
#include "GPRS_Shield_Arduino.h"
#include <SoftwareSerial.h>
namespace K {  //to fix conflict
#include <Keypad.h>
};
#define MESSAGE_LENGTH 10
#include <Wire.h>
#include <LiquidCrystal_I2C.h>

LiquidCrystal_I2C lcd(0x27, 2, 1, 0, 4, 5, 6, 7, 3, POSITIVE);

char Phone[5][20] = {}; //insert phone numbers want to use
byte condition = 0, //which condition the system is in
     option = 4; // options of the fire alarm system

char message[MESSAGE_LENGTH];
char datetime[24];
byte message_index = 0;

unsigned long pre_setoff_time = 0;
unsigned long now_setoff_time = 0;

unsigned long now_incCall = 0;
unsigned long pre_incCall = 0;
unsigned long now_Ar_call = 0;
unsigned long pre_Ar_call = 0;
unsigned long now_blink = 0;
unsigned long pre_blink = 0;

unsigned long now_check_mess = 0;
unsigned long pre_check_mess = 0;

unsigned long lcdON_time = 0;
unsigned long wait_time = 10000;
bool displayON = true;


bool phone_match = false;
bool tellOwner = false;
bool inc_call;

byte flameSen = 13;
byte smokeSen = 16;
byte led = 15;
byte buzzer = 14;
int smokeValue = 0;
int flameValue = 0;
bool fire = false;
bool gasleak = false;

bool alarm_call = true;
bool currentCall = false;

char inc_phone[20] = {0};
byte order = 0;

bool button_kpd = true;

const int PIN_TX = 2;
```

```
const int PIN_RX = 3;
const int BAUDRATE = 9600;
GPRS gprs(PIN_TX, PIN_RX, BAUDRATE);

//set up the keypad
const byte ROWS = 4;
const byte COLS = 3;
char buttons[ROWS][COLS] = {
  {'1', '2', '3'},
  {'4', '5', '6'},
  {'7', '8', '9'},
  {'*', '0', '#'}
};
byte rowPins[ROWS] = {4, 5, 6, 7};
byte colPins[COLS] = {10, 11, 12};
K::Keypad kpd = K::Keypad(makeKeymap(buttons), rowPins, colPins, ROWS,
COLS);


void setup() {
  gprs.checkPowerUp();//start the sim shield
  Serial.begin(9600);
  while (!gprs.init()) {
    delay(1000);
  }
  lcd.begin(16, 2);
  lcd.noBacklight();
  pinMode(led, OUTPUT);
  pinMode(buzzer, OUTPUT);
  pinMode(flameSen, INPUT);
  pinMode(smokeSen, INPUT);

}


void loop() {
  char key = kpd.getKey();
  if (button_kpd) {
    if (key) { //if a key is pressed
      Serial.print(key);

      if (key == '*') {//press * to start the lcd
        condition = 1;
        lcd.backlight();
        lcd.setCursor(0, 0);
        lcd.print("1:HM1 2:HM2 3:AW ");
        lcd.setCursor(0, 1);
        lcd.print("4:OFF 5:PH ");
        displayON = true;

      }

      else if (key == '#') { //press # to turn off lcd
        lcd.clear();
        Menu();
        displayON = true;
        lcd.noBacklight();
      }
      else {
        lcdON_time = millis();
        if (condition == 1) {//Select mode menu
          if (key == '1') { //Home mode 1
```

```
            lcd.clear();
            lcd.print("Home mode 1");
            option = 1;
          }
          else if (key == '2') { //Home mode 2
            lcd.clear();
            lcd.print("Home mode 2");
            option = 2;
          }
          else if (key == '3') { //Away mode
            lcd.clear();
            lcd.print("Away mode");
            option = 3;
          }
          else if (key == '4') {//Turn off mode
            lcd.clear();
            lcd.print("Turn off");
            option = 4;
          }
          else if (key == '5') { //show saved phone numbers
            displayON = true;
            condition = 2;
            showPhoneNo();
          }
        }
      }
    }
  }
  if (millis() - lcdON_time >= wait_time) {//lcd sleep after 10s
inactive
    lcdON_time = millis();
    lcd.noBacklight();
    lcd.clear();
    displayON = true;
  }

  opMode(gasleak, fire);
  if (fire) {
    FireAlarm();
  }
  else {
    now_check_mess = millis();
    if (now_check_mess - pre_check_mess >= 3000) {//to check if there
are any message from owner(s)
      pre_check_mess = millis();
      message_index = gprs.isSMSunread();
    }
    checkIncMess();
  }
}


void opMode(bool gasRead, bool fireRead) {//options to choose
  smokeValue = analogRead(smokeSen);
  flameValue = digitalRead(flameSen);

  if ((smokeValue > 400) && (flameValue == false))
  {
    gasRead = true;
  }
  else
  { gasRead = false;
```

```
  }

  if (flameValue) {//this flame sensor has reverse value, the author
do not know why
    fireRead = false;
  }
  else {
    fireRead = true;
  }
  switch (option) {
    case 1://option 1: Home mode 1
      Serial.println(flameValue);
      if (!gasleak) {
        if (gasRead) {
          gasleak = true;
          pre_setoff_time = millis();
          digitalWrite(led, HIGH);
        }
      }
      else {
        now_setoff_time = millis();
        if (now_setoff_time - pre_setoff_time >= 7000) {
          if (gasRead) {
            digitalWrite(buzzer, HIGH);
          }
          else {
            digitalWrite(led, LOW);
          }
          gasleak = false;
        }
      }
      break;

    case 2://option 2:Home mode 2
      if (!fire) {
        if (fireRead) {
          fire = true;
        }
      }
      break;

    case 3://option 3: Away mode
      if (!fire) {
        if (fireRead == true || gasRead == true) {
          fire = true;
        }
      }
      break;

    case 4://option 4: turn off the system
      turnOFF();
      break;

    default: option = 4;
  }
}



void Menu() { //return to the default state
  condition = 0;
}
```

```
void showPhoneNo() {// for displaying the phone number
  lcd.clear();
  if (condition == 2) {
    int z = 0; //display 2 things in 1 line

    for (int i = 0; i < 4; i++) {
      if (z + 1 == i / 2) displayON = true;
      if (displayON == true) {
        z = i / 2;
        lcd.setCursor(0, z);
        displayON = false;
      }
      lcd.print(i + 1); lcd.print(':');
      for (int a = 4; a >= 0; a--) { //show saved phone number and its
last 5 numbers
        lcd.print(Phone[i][strlen(Phone[i]) - a - 1]);
      }
      lcd.print("  ");
    }
  }

}

void FireAlarm() { //alarm when a fire or a gas leakage is detected
  Serial.println(flameValue);
  if (!phone_match) {
    if (!tellOwner) {
      while (alarm_call == true) {
        if (strcmp(Phone[order], "0") != 0) {
          gprs.callUp( Phone[order]);
          currentCall = true;
          order++;
          break;
        }
        else order++;
        if (order > 2) {
          if (!currentCall) {
            alarm_call = false;
          }
          else order = 0;
        }
      }
      tellOwner = true;
      pre_Ar_call = millis();
      if (alarm_call == true)
        {button_kpd = false;}
      else button_kpd = true;
    }
    else {
      now_Ar_call = millis();
      if (now_Ar_call - pre_Ar_call >= 6000) {
        digitalWrite(led, HIGH);
        digitalWrite(buzzer, HIGH);
        if (!button_kpd) {
          delay(2000);
          gprs.hangup();
          button_kpd = true;
        }
        inc_call = gprs.isCallActive(inc_phone);
        if (inc_call) {
          checkIncCall();
```

```
          Serial.println(inc_phone);

        }
      }
      else if (now_Ar_call - pre_Ar_call < 6000) {//the led start to
blink for early warning
        now_blink = millis();
        if (now_blink - pre_blink >= 100) {
          digitalWrite(led, !digitalRead(led));
          pre_blink = millis();
          inc_call = gprs.isCallActive(inc_phone);
          if (inc_call) {
            checkIncCall();
            Serial.println(inc_phone);

          }
        }
      }
      if (now_Ar_call - pre_Ar_call >= 20000) {
        tellOwner = false;
        now_Ar_call = 0;
      }
    }
  }
  else {
    now_incCall = millis();
    if (now_incCall - pre_incCall >= 200) {
      pre_incCall = millis();
      inc_call = gprs.isCallActive(inc_phone);
      if (inc_call) {
        checkIncCall();
        Serial.println(inc_phone);

      }
    }

  }
}

void turnOFF() { //turn off the alarm and return the system to default
state
  digitalWrite(led, LOW);
  digitalWrire(buzzer, LOW);
  gasleak = false;
  fire = false;
  phone_match = false;
  button_kpd = true;
  order = 0;
  currentCall = false;
}

void checkIncMess() {//check incoming messages for commands
  if (message_index > 0) {
    char inc_phone[20];
    char inc_buffer[20];
    gprs.readSMS(message_index, message, MESSAGE_LENGTH, inc_buffer,
datetime);
    strcpy(inc_phone, inc_buffer);
    gprs.deleteSMS(message_index);
    for (int i = 0; i < 4; i++) {
      if (strcmp(Phone[i], inc_phone) == 0) {
        phone_match = true;
```

```
        i = 5;
      }
    }
    if (phone_match) {
      if (!strcmp(message, "1") || !strcmp(message, "2") ||
!strcmp(message, "3") || !strcmp(message, "4")) { //use message to set
options
        option = message[0] - '0';
        displayON = true;
        Serial.println(option);
      }
    }
    phone_match = false;
  }
  message_index = 0;
}


void checkIncCall() { //check incoming call for commands
  gprs.hangup();
  for (int i = 0; i < 3; i++) {
    if (strcmp(Phone[i], inc_phone) == 0) {
      i = 5;
      option = 4;
      Serial.println("Phone match");
    }
    phone_match = true;
  }
  if (option == 4) {
    gprs.sendSMS(inc_phone, "Alarms stopped");

  }
  memset(inc_phone, '\0', sizeof(inc_phone));
}
```