DESIGN OF AN AUTOMATED ILLUMINATED EMERGENCY EXIT DOOR SYSTEM (AUTO IEED)

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This report is submitted in partial fulfilment of the requirements for the degree of Bachelor of Electronic Engineering with Honours

Faculty of Electronics and Computer Engineering
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2021

DECLARATION

I declare that this report entitled "Design of An Automated Illuminated Emergency Exit Door System (Auto IEED)" is the result of my own work except for quotes as cited in the references.

Signature : ....

Author : Ooi Ching Yi

Date : 04 August 2021

APPROVAL

I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award of Bachelor of Electronic Engineering with Honours.

Signature : ....

Supervisor Name : Dr. Siva Kumar A/L Subramaniam

Date : 04 August 2021

DEDICATION

I dedicate my dissertation work to my partner, Sum Young Foo, for his continuous support and encouragement throughout the implementation and installation process. I appreciate all he has done and I am sincerely thankful for having him as my best cheerleader. I also dedicate this work to my unique family for their unconditional love. They never left my side and taught me the value of hard work.

ABSTRACT

In a building fire event, occupants are distracted by thick smoke and carbon dioxide fumes that result in an unguaranteed evacuation. Using the conventional exit signs to the exit doors is insufficient to guide the occupants from safety while it becomes more critical in the multi-story buildings. Even finding an exit door is a risk as exiting a door without a clue of what lies on the other side of the door is a great threat. Therefore, there is a need to develop a system to guide the building occupants in evacuation. The system can identify and analyse the presence of real-time fire in the specific location of a building and send a warning notification when the threshold levels are exceeded. The "traffic light" concept system is indicated with piezo buzzers and flashing red and green LEDs located at the exit points. This project involves Internet of Things (IoT) technology using NodeMCU ESP32, ThingSpeak platform, and Pushover application. The experimental result shows that whenever the temperature, gas and flame levels are beyond the threshold, the authorised individuals receive a notification on the respective Wi-Fi connected mobile devices. Through this project, the evacuation will become efficiently faster and safer.

ABSTRAK

Dalam kejadian kebakaran bangunan, penghuni diganggu oleh asap tebal dan asap karbon dioksida yang menyebabkan evakuasi yang tidak terjamin. Penggunaan tanda keluar konvensional ke pintu keluar adalah tidak mencukupi untuk membimbing penghuni dari keselamatan sementara ia menjadi lebih kritikal di bangunan-bangunan bertingkat. Bahkan mencari pintu keluar adalah berisiko kerana keluar dari pintu tanpa petunjuk apa yang terada di sebelah pintu merupakan ancaman yang besar. Oleh itu, sebuah sistem perlu dikembangkan untuk membimbing penghuni bangunan dalam evakuasi. Sistem tersebut boleh mengenalpasti dan menganalisis keadaan kebakaran di lokasi tertentu dalam bangunan dan mengirim pemberitahuan amaran apabila tahap ambang terlampaui. Sistem berkonsep "lampu isyarat" ini ditunjukkan dengan buzzer piezo dan LED merah dan hijau berkelip yang diletakkan di pintu keluar. Projek ini melibatkan teknologi Internet of Things (IoT) dengan NodeMCU ESP32, platform ThingSpeak, dan aplikasi Pushover. Hasil eksperimen menunjukkan bahawa setiap kali suhu, tahap gas dan nyalaan melebihi ambang batas, individu yang berkuatkuasa akan menerima pemberitahuan pada peranti mudah alih yang disambungkan dengan Wi-Fi masing-masing. Melalui projek ini, evakuasi akan menjadi lebih cepat dan selamat.

ACKNOWLEDGEMENTS

I would like to express my deepest gratitude to Dr. Siva Kumar A/L Subramaniam for his patient guidance and constructive advice during the development of the project. He has been a fantastic lecturer, mentor and project supervisor who offers comments and suggestions with a perfect blend of insight and humour. I would also like to extend my thanks to the laboratory helper, En. Imran bin Mohamed Ali for his assistance in the PCB fabrication process and Universiti Teknikal Malaysia Melaka for the financial support. This project would not have been possible without the constant guidance, assistance and support of many people.

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LIST OF SYMBOLS AND ABBREVIATIONS

AC	:	Alternative Current
AENS	:	Autonomous Evacuation Navigation System
CAN	:	Controller Area Network
CFR	:	Code of Federal Regulation
CO	:	Carbon Monoxide
CWS	:	Continuous Way-Finding System
FDAS	:	Fire Detection and Alarm System
FRDM	:	Fire and Rescue Department of Malaysia
GPIO	:	General Purpose Input/Output
HSA	:	Sultanah Aminah Hospital
HTTP	:	Hypertext Transfer Protocol
IC	:	Integrated Circuit
IDE	:	Integrated Development Environment
IDLH	:	Immediately Dangerous to Life and Health
IoT	:	Internet of Things
IR	:	Infrared
JBPM	:	Jabatan Bomba dan Penyelamat Malaysia
LEDs	:	Light-Emitting Diodes
NFPA	:	National Fire Protection Association

NIOSH	:	National Institute for Occupational Safety and Health
OSHA	:	Occupational Safety and Health Administration
OSHA 1994	:	Occupational Safety and Health Act
PC	:	Personal Computer
PCB	:	Printed Circuit Board
PLM	:	Photoluminescent Material
RF	:	Radio Frequency
UV	:	Ultraviolet
VR	:	Virtual Reality
WSN	:	Wireless Sensor Network

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

The first chapter of this thesis opens with the motivation of the project and further describes the emergency exit signs and emergency exit routes. It is followed by the problem statements, objectives, scope and significance of the project. The chapter concludes with the outline of the thesis.

1.1 Motivation of Project

One of the main elements of a building is the safe egress of all occupants out of the building at a fire event. The inability to provide safe evacuation in the early phase of fire contributes to the risk of mass casualties. In spite of the fact that the medically defined reasons for fatal casualties in building fires are harmful gases and depletion of oxygen, the grounds are principally attributable to a failure to help the occupants get out of the building in the underlying phase of the fire. The determinant reasons for the failure to give a quick and safe escape are the panic responses of the occupants and the environmental deficiency of the building. A number of fire events with mass casualties strikingly embody the importance of safe evacuation in the initial phase of fire and the danger of losses as a result of the inability to guarantee quick evacuation [1].

1.1.1 Emergency Exit Signs

An illuminated emergency exit sign is an indicator to inform occupants in a building about the safe egress routes in emergencies [2]. A conventional exit sign is shown in Figure 1.1. These exit signs are regularly found in the presence of other colours [2]. Understanding the significance of an emergency exit sign is vital for evacuating from a building during a disaster or fire event [3].

Figure 1.1: Conventional exit sign

Based on the International Organization for Standardization 7010:2011, there are leftward and rightward running-man exit signs reflecting the location of an exit door. The running-man exit signs are depicted in Figure 1.2. Nevertheless, there is neither an application rule concerning which direction the sign should point nor a rule where it should be attached in the horizontal dimension [3].

Figure 1.2: Leftward and rightward running-man exit signs

Emergency exit signs are necessary for all public buildings, especially multi-story buildings, where there are many people, such as schools, dormitories, college and university buildings, hospitals, movie theatres, concert venues and auditoriums, nursing homes, senior centres, etc. It is required where a large number of occupants would need to evacuate from the building due to a disaster or a fire event. Emergency exit signs should be noticeable from afar and in all directions. Besides, they ought to be illuminated well enough during the failure of power for ease of visibility [4].

1.1.2 Emergency Exit Routes

Emergency evacuation plans are regularly developed under the expectation that occupants in a building will utilise way-finding methods, such as taking the shortest distance route to the closest exit [5]. However, there is still a loss of life in emergency situations every year because of inefficient evacuation plans. Generally, occupants do not obey the emergency exit signs during hazardous situations, but they respond surprisingly because of the panic and anxiety to get out of the building. The evacuation plans ordinary symbolise a particular exit route and do not consider the possibility of proposing alternative routes in case of high congestion or blockages [6].

Based on 29 Code of Federal Regulation (CFR) 1910.34(c), the Occupational Safety and Health Administration (OSHA) defines an emergency exit route as a continuous and unobstructed path of exit travel from any point within a workplace to a place of safety (including refuge areas) [7]. An emergency exit route is crucial as it provides a safe and clear path for evacuation. First responders, such as policemen or firefighters, may also utilise the emergency exit routes to enter the building. An exit route comprises three parts: the exit access, the exit and the exit discharge [7].

(a) Exit Access

The portion of an exit route that leads to an exit, as shown in Figure 1.3 [7].

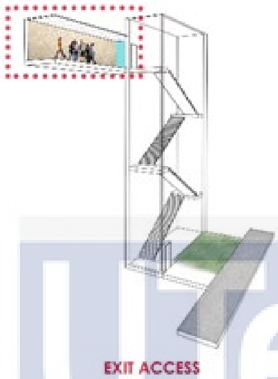


Figure 1.3: Exit access

(b) Exit

The portion of an exit route that is generally separated from other areas to provide a protected way of travel to the exit discharge, as shown in Figure 1.4 [7].

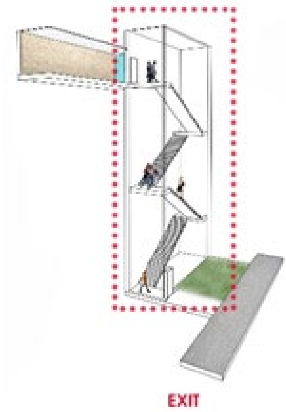


Figure 1.4: Exit

(c) Exit Discharge

The portion of the exit route that leads directly outside or to a street, walkway, refuge area, public way, or open space with access to the outside, as shown in Figure 1.5 [7].

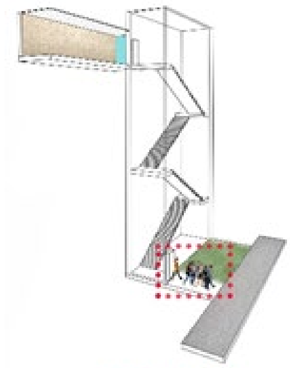


Figure 1.5: Exit discharge

1.2 Problem Statements

The problem statements outline and explain the disadvantages of the current emergency exit door system.

1.2.1 Invisibility of Conventional Exit Sign

In a building fire event, occupants are distracted by thick smoke and carbon dioxide fumes. The use of conventional exit signs to the emergency exit doors is insufficient to guide the building occupants from safety while it becomes even critical in a multi-story building. This results in an unguaranteed evacuation from the building. Figure 1.6 shows the illuminated conventional exit signs in a dark room.

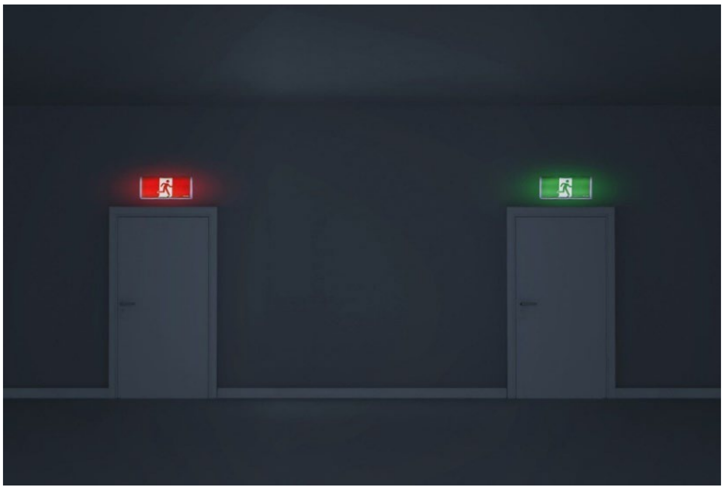


Figure 1.6: Illuminated conventional exit signs in dark room

1.2.2 Clueless on Other Side of Emergency Exit Door

In a building fire event, occupants are distracted with think smoke and carbon dioxide fumes. They tend to get panic and look for an emergency exit door. However, simply entering an emergency exit door might put the life of the occupants at risk as they have no clue of what is lied on the other side of the door. This greatly threatens someone in such chaos.

1.3 Objectives

The objectives of this project are:

- To design and develop an emergency exit door system with multiple sensors to detect the occurrence of fire and assist the people in an evacuation.
- To analyse the performance of the proposed system in terms of luminous intensity.

1.4 Scope of Project

The proposed system involves four major elements: power supply unit, control and processing unit, alerting and indicating unit, and detector. The detector system is constructed by the integration of DHT11 temperature and humidity sensor, MQ-2 gas/smoke sensor and KY-026 flame sensor with NodeMCU ESP32 microcontroller. The sensors are bought off the shelf and the datasheets provided by the manufacturer are used for their specification. The alerting and indicating unit is constructed by the integration of piezo buzzer and SK6812 LEDs with NodeMCU ESP32 microcontroller.

In practice, this project is designed to be implemented at the exit of an exit route in a multi-story building. Thus, the Auto IEED system is intended to be installed at both sides of an emergency exit door on each layer. A number of two layers or floors are used in the execution of this project. Hence, there are four Auto IEED systems mounted in the building. The installation of an Auto IEED system is such that its two strips of 60 LEDs are on the opposite side.

In the implementation of this project, a constant 5 V input voltage is required to supply the alerting and indicating unit and detector system. The smoke sensor on each level of the building is expected to sense the developing fire on that level respectively. It is designed to activate at the threshold level of smoke density. Moreover, I assume that there is no smoking or children playing with matches around the smoke sensors because it will lead to an inadequate warning of fires.

The electronic components used in the system have a probability of failing at any time, though designed to last for many years. Hence, it is suggested to check, maintain and replace the components for a precautionary measure. Also, the components of the system will not function without an electrical power supply. Thus, the batteries used in the system should be serviced or replaced regularly as battery backup is not provided when alternative current (AC) power fails.

1.5 Significance of Project

The world population has risen to over 6.3 billion people, and there are now over 400 cities with a population of over a million people. The growth of population is an underlying factor that contributes to the demand for multi-story buildings due to the limitation of land property. The emergency exit door system is required in all public buildings, especially multi-story buildings, where there are many people. It is necessary when a large number of occupants would need to evacuate from the building due to an unexpected fire event or disaster.

The feature of the project is that its ability to detect the danger behind an emergency exit door. With a reliable emergency exit door system in place, the life of building occupants would not be at risk during an evacuation.

1.6 Outline of Thesis

The thesis is organised into five chapters. Chapter 1 begins with an introduction to the background of the project. It is followed by the problem statements, objectives, scope and significance of the project. Chapter 2 presents a review of the literature related to the field of the project title. It brings out where the literature gaps are and how the project helps to fill in one or more of these gaps. Chapter 3 provides a detailed description of the selected procedure used and the data collection method. It covers every component or material used in implementing the project. Chapter 4 presents and discusses the results obtained with reference to the objectives of the project. Chapter 5 summarises the essential findings of the project and provides potential future work for the readers.

CHAPTER 2

LITERATURE REVIEW

This chapter presents the background of the study and summarises the previous works relevant in the field of the project title analytically. It highlights the literature gaps and how the project "Design of An Automated Illuminated Emergency Exit Door System" helps to fill in one or more of these gaps.

2.1 Statistics of Fire in Malaysia

Fire performs a crucial role in the evolution of human history. In ancient times, fire was used as a weapon to protect humans from wild animals, while it is used to improve land fertiliser and prepare food nowadays. It can likewise bring catastrophic disasters that lead to fatalities and casualties as well as damages to the property and environment. From the perspective of chemistry, fire is an oxidation response with the liberation of energy. The knowledge of modern science empowers us to understand the properties of fire and apply it to different contexts for the advantage of human beings. Besides, the knowledge of chemistry allows us to comprehend the causes of fire, understand the conditions in which fire could occur, and examine any incident related to fire. For years, the recurrence of the fire has been documented, and these data are helpful for fire prevention, infrastructure planning and law enforcement [8].

The Fire and Rescue Department of Malaysia (FRDM) attended to 33,640 fires around the country in 2013, which is an average of 92 cases a day. Figure 2.1 shows the statistics of fire breakouts in Malaysia from 2007-2013 [8].

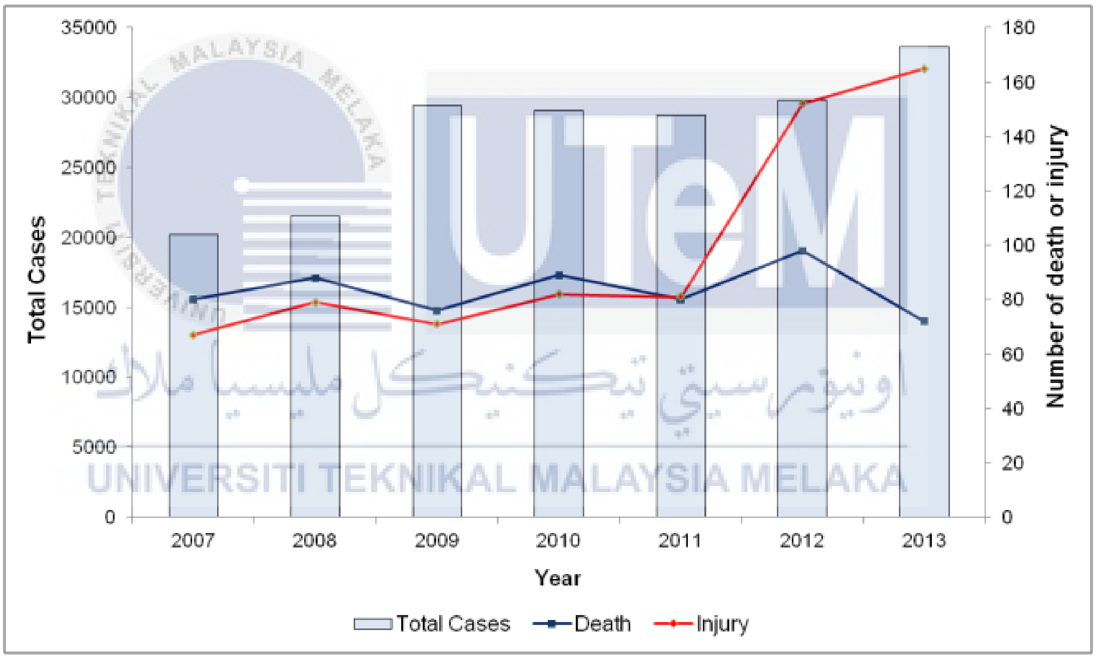


Figure 2.1: Statistics of fire breakouts in Malaysia, 2007-2013

The statistics of fire breakouts remain stable from 2009 to 2012. A sharp increase of fire incidents in 2013 has executed 72 people, but it was the lowest number of fatalities for the past seven years. The statistics of death is associated with instant death at the spot of an event, and the real number of deaths due to fire is assuredly higher. In short, the statistics of death because of fire outbreaks are constant despite the fact that the incident of these cases was more frequent happened. Consequently, these figures are considered significant as fire examination as well as the safety and prevention steps should be executed in the country [8].

2.2 Case Study

A fire was doused at the Sultanah Aminah Hospital (HSA) on 28th June 2020, as shown in Figure 2.2, resulting in the evacuation of 24 patients. The fire broke out at one of its female wards. According to Health Minister Datuk Seri Dr Adham Baba, the incident happened at around 3:00 pm. It was put under control by the emergency response team of the hospital at first. However, the fire flared back, and the Fire Rescue Department (JBPM) was called. They arrived within five minutes and put out the fire within 10 minutes. The cause of the fire is still under investigation [9].

Figure 2.2: Fire at Sultanah Aminah Hospital on 28th June 2020

Moreover, on 25th October 2016, a fire broke out at the intensive unit care of the hospital, as shown in Figure 2.3. The fire incident resulted in the death of six patients and forced hundred others to be evacuated. It was reported that a burnt capacitor in one of the ceiling lights had been identified as one of the factors of the fire at the hospital [10].

Figure 2.3: Fire at Sultanah Aminah Hospital on 25th October 2016

A fire broke out at a religious (tahfiz) school at Jalan Datuk Keramat in Kuala Lumpur on 14th September 2017, as shown in Figure 2.4, killed 23 people. The majority of the victims are teenagers. They were trapped behind barred windows and a blocked exit in the dormitory. According to the Kuala Lumpur chief police Amar Singh, the firefighters rushed to the scene after receiving a distress call at 5:41 am. They took an hour to out the blaze which started on the top floor of the three-storey building. As states by the fire department senior official Abu Obaidat Mohamad Saihalimat, the fire broke out closed to the door of the boys' dormitory and trapped the victims as it was the only entrance while the windows are grilled. The cause of the fire was believed to be an electrical short-circuit [11].

Figure 2.4: Fire at religious school in Kuala Lumpur on 14th September 2017

2.3 Standard of Safety Requirement

The National Fire Protection Association (NFPA) 101, the so-called Life Safety Code, is the most broadly utilised source for strategies to insure individuals based on building construction, protection, and occupancy aspects that minimise the impacts of fire and related dangers. Unique in the field, it is the only document that contains life safety in both new and existing structures [12].

The Occupational Safety and Health Administration (OSHA) is set up to assist in protecting labours from dangers in the work environment. It extensively adopts extant health and safety standards [13]. OSHA requires all associations to have an emergency action plan that must comprise methods of reporting fires and other emergencies, rescue and medical duties, and evacuation procedures [14].

In Malaysia, the Occupational Safety and Health Act (OSHA 1994) is an act that provides the authoritative framework to ensure the safety, health and welfare within all Malaysian workforce and to secure others against dangers to safety or health regarding the activities of persons at work. It was established on 24th February 1994. It is a functional tool superimposed on existing safety and health enactment [15].

The NFPA and OSHA have identical demands for externally illuminated emergency exit signs. In the 1940s, the NFPA created and published standards for emergency exit signs after a burst incident in Manhattan garment factory which killed almost 150 people. The use of the present emergency exit signs and lights is governed by these local fire codes together with the work environment standards from the OSHA [16].

Every employer needs to install plainly visible emergency signs at all exits and provide adequate lighting along the exit routes as stated in OSHA 1994. The emergency exit signs ought to have distinctive colouring and reliable illumination to guarantee visibility at all times. These exit signs must be enlightened to a surface value of five foot-candles (54 lux), which is the minimum suggested brightness in a carport [16]. A foot-candle is identical to the amount of light that falls on a surface that is one foot away from a single candle. Meanwhile, a lux is the amount of light that falls on a surface that is one meter away from a candle. The relationship between 1 foot-candle and 1 lux is illustrated in Equation (2.1) and Figure 2.5 [17].

$$1 \text{ foot-candle} = 10.764 \text{ lux} \quad (2.1)$$

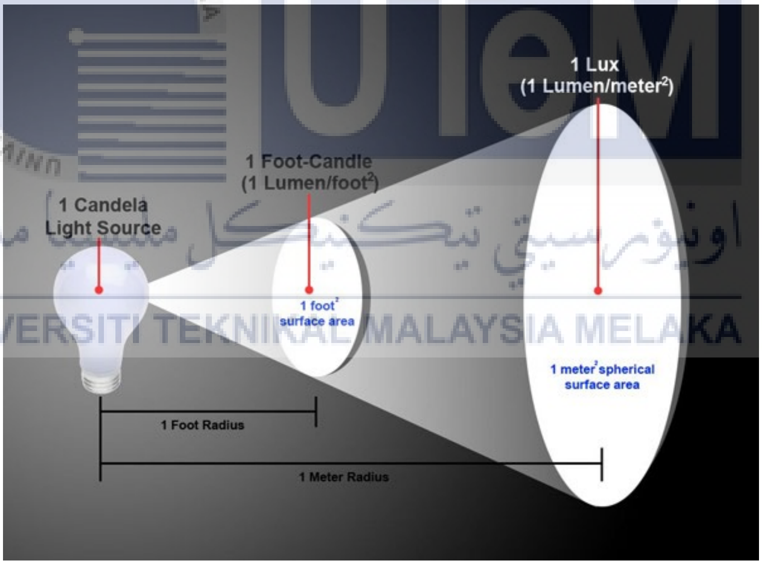


Figure 2.5: Relationship between 1 foot-candle and 1 lux

In NFPA 101, the prerequisites for illumination and visibility of emergency exit signs overlap with OSHA. Both require that the illumination of emergency exit signs is five foot-candles. OSHA and NFPA take visibility, continuous illumination, and contrast as the fundamentals of functioning emergency exit signs [16].

According to the 29 Code of Federal Regulation (CFR) 1910.37(a)(3), exits routes should be free and unobstructed [7]. The unclear and blocking exit routes and doors will cause delay, panic, and confusion in the emergency case and act as a safety hazard. OSHA regulations require that the exit routes are unblocked by any material or equipment. The exit access (i.e. fire doors) must not pass through a lockable room nor directly into a dead-end corridor [7].

2.4 Past Works

This section provides an overview of technical research regarding the project. A few examples of research addressing the specific application and effectiveness are included.

2.4.1 Safety Water Sprinkler System at Emergency Exit

Mohd Azrul Afriza Zainuddin et al. (2018) found that the existing fire sprinkler is unable to extinguish the fire for a wide range, especially at the emergency exit. The fire sprinkler with a pendant header is installed at the centre of the ceiling along the corridor and is unable to cover all the fire. Hence, occupants are unable to escape from the building and firefighters face difficulty entering the building if there is a fire near the emergency exit door [18].

Mohd Azrul Afriza Zainuddin et al. (2018) designed and developed a new safety water sprinkler system at the top of the emergency exit door, which sprinkles water automatically when heat and smoke are detected. Figure 2.6 illustrates the concept of the safety water sprinkler system. It is an efficient safety system as it is easy to install and have a low maintenance cost. The designed system uses a water pump as the pumping system. Thus, it can cover an area of up to 2 metres. The new safety water sprinkler system is aimed to put out the fire from blocking the emergency exit door. It is estimated that the occupants will evacuate the building within 4 minutes [18].

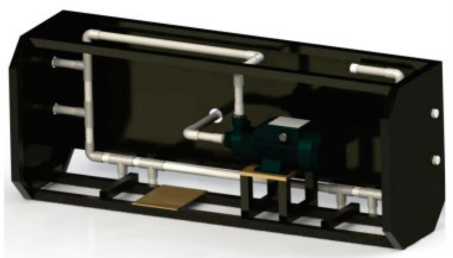


Figure 2.6: Concept of safety water sprinkler system

However, during a building fire event, water is sprinkled onto the fire, heated up by the heat from the fire and turned into steam. Consequently, the conventional emergency exit signs are beclouded by the thick smoke and steam. The occupants could not locate the emergency exit door and evacuate the building within 4 minutes. Besides, the firefighters could not find the exact spot of the fire as there is no indication from the system.

2.4.2 Modelling the Way-Finding Queuing Bottleneck in Autonomous Evacuation Navigation System Using Simulation Approaches

The studies of Samah Khyrina Airin Fariza Abu et al. (2015) focused on the time taken to reach a nearby emergency exit. In an emergency, the time taken to evacuate depends on a variety of bottlenecks, such as queuing stages. Hence, Samah Kyyrina Airin Fariza Abu et al. proposed an autonomous evacuation navigation system (AENS) to identify and minimise the queuing bottleneck. The simulation approach of the evacuation is intended to solve an indoor way-finding problem. It is independent, reliable and capable of excluding human as an agent in the emergency evacuation. As a result, the design of AENS identifies, accelerates and minimises the queuing bottleneck. It has also verified that the evacuation time to the emergency exit has been reduced [19].

In short, way-finding that is searching for the safest and shortest path to the emergency exit door is considered as an important issue, especially for the occupants who are not familiar with the structure of the building.

2.4.3 Colour of Emergency Exit Signs

Recent studies by Max Kinateder et al. (2019) argued that the way occupants thought they would react in emergency situations (red = exit) dissociates with the way they did react in simulated emergency situations (green = exit). The illuminated emergency exit signs are frequently found in the presence of other colours, which may confuse occupants when looking for a safe exit door to evacuate the building. Such confusion tends to cause dangerous outcomes, especially if the occupants misinterpret the emergency sign colours [2].

Therefore, Max Kinateder et al. (2019) used a virtual reality (VR) method to infer the colour of emergency exit signs in a simulated emergency evacuation. Participants were allocated to a virtual room with two doors (left and right), each with a different colour of illuminated emergency exit signs, as shown in Figure 2.7 [2].

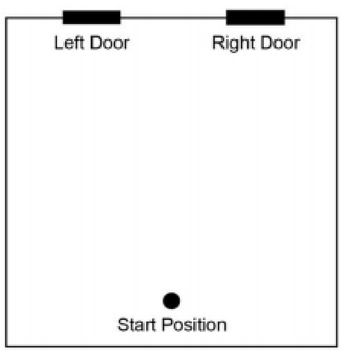


Figure 2.7: Schematic overview of experimental setup

On each test, participants headed towards the door, which they thought was the emergency exit when the fire alarm activated. Correspondingly, participants predominantly headed towards the door with green illuminated emergency exit signs. Figure 2.8 shows the screenshots of each exit sign as displayed in the virtual environment [2].

Figure 2.8: Screenshots of each exit sign as displayed in virtual environment

Past studies by Troncoso et al. (2016) suggested occupants infer that the colour of emergency exit signs is green. Participants from China and Europe were asked to have a seat and navigate a virtual maze using a gamepad. When the participants ran into bifurcations in the maze, they could follow red or green signs. As a result, most of the participants were likely to follow green signs [20].

In a nutshell, these findings have implications for the project. Behavioural evaluations for egress safety are essential.

2.4.4 Design and Test of a Non-Invasive Solution for Reducing Fire Egress Time in Building Heritage Scenarios

The studies of Gabriele Bernardini et al. (2017) focused on how to assist the elderly in indoor evacuation way-finding. Emergency safety for the elderly is essential due to the rise of population ageing. Way-finding is an elementary task in evacuation as the elderly have to receive correct information about the routes to be used in the clearest and simplest way in order to minimise incorrect behavioural options and build egress time. A "behavioural design" approach of the elderly facilities is promoted: to understand behaviours and requirements in an emergency; to design systems for interaction in an emergency; to test results in a real environment or by validated simulation [21].

Gabriele Bernardini et al. (2017) proposed a forceful way-finding system with continuous application of photoluminescent material (PLM) tiles along the routes, as shown in Figure 2.9. Resultantly, the evacuation speed of the elderly is increased significantly (more than 20%) compared to the conventional system [21].

Figure 2.9 (a): Adhesion of PLM strips along stairs

Figure 2.9 (b): Adhesion of PLM directional arrows on floor

Nevertheless, the evacuation of the elderly by responding to the alerting signal given when a fire is discovered and making their way based on the continuous PLM signs to an emergency exit door might put their life at risk. This is because the elderly have no idea of what is lied on the other side of the emergency exit door.

2.4.5 How Photoluminescent Way-Finding Can Improve Occupants' Evacuation with No Architecture Modifications

The studies outlined by Marco D'Orazio et al. (2016) suggested that the implementation of a good emergency evacuation way-finding system is an efficient way to assist building occupants in an evacuation, especially in a smoky and blackout circumstance. Architectural heritage with many weighty wooden structures has a higher risk of fire. Generally, increasing the fire safety of the architectural heritage clashes with conserving the uniqueness of the building due to the requirement of permanent interventions to follow the current severe regulations. The safety of the building occupants depends on their behaviours and responsibilities to evacuate the building promptly. Thus, improvement of interventions might be deficient in securing the safety level of building occupants, especially in an overcrowded area. Besides, occupants might not be familiar with the building structure itself [22].

Marco D'Orazio et al. (2016) proposed a continuous way-finding system (CWS), which is a reversible, removable and low-impact system based on photoluminescent materials (PLM). The system comprises PLM tiles along evacuation routes (both corridors and stairs). The tests at the Italian style historical theatre "Gentile da Fabriano" involved more than 100 people in the smoky and blackout circumstance. As a result, the motion speed of a single occupant rises up to 50% and the total evacuation time of the entire building is reduced down to 25% compared to the traditional punctual system. CWS tends to increase the safety level of occupants in the historical building [22].

However, the evacuation of the occupants by reacting to the alarming signal given when a fire is discovered and making their route along with the PLM tiles to an emergency exit door might put their life in danger. This is because the building occupants have no clue on the other side of the emergency exit door.

2.4.6 IoT-Based Intelligent for Fire Emergency Response Systems

J. S. Jang et al. (2013) realised that the conventional evacuation guidance, such as emergency exit lights are insufficient to assist the building occupants during a fire, where toxic gases can be produced [23]. Moreover, Chang-Su Ryu (2015) found that the use of emergency exits or guidance markers needs to be possible for fast evacuation due to fire, building collapse, earthquakes, or ageing of buildings as the structural characteristics of buildings have become involved and augmented [24].

The conventional emergency exit guides do not take into account the exact location of the fire and simply direct occupants to the nearest emergency exit. Consequently, this may put the life of occupants at risk if the fire has happened at the emergency exit, but the occupants are assisted towards it [24].

For that reason, Chang-Su Ryu (2015) proposed an Internet of Things (IoT)-based intelligent fire emergency response system. It can control the directional guidance wisely according to the time and location of a fire or disaster to reduce the loss of occupants' life. The design of the system environment composition modules consists of an Ember EM250 chipset, sensor modules, a CDD controller, a communication module, a power module, a CSD controller, a light-emitting diode (LED) display, and buzzers. Besides, the sensors for smoke, flame, and heat are integrated into the emergency exit lights. They are powered by cable wiring and batteries, and configured as bidirectional indicators via wireless sensor network (WSN) communication, as shown in Figure 2.10 [24].

Figure 2.10: Integration of emergency exit lights with sensors

In brief, the structural characteristics of multi-storey buildings have become involved and augmented. Hence, it is necessary to have a system that can facilitate the occupants to evacuate from the buildings quickly and safely during blackouts due to natural disasters, such as fire.

2.4.7 Hybrid IoT Based Hazard Detection System for Buildings

The studies of Nisarga B L et al. (2020) focused on implementing a smart wireless hazard preventing system for providing effective monitoring and automating services. It comprises many sensors, such as temperature, fire, light and smoke, integrated into the single system to detect the hazards in a timely manner and generate an alarm. Figure 2.11 depicts the system architecture [25].

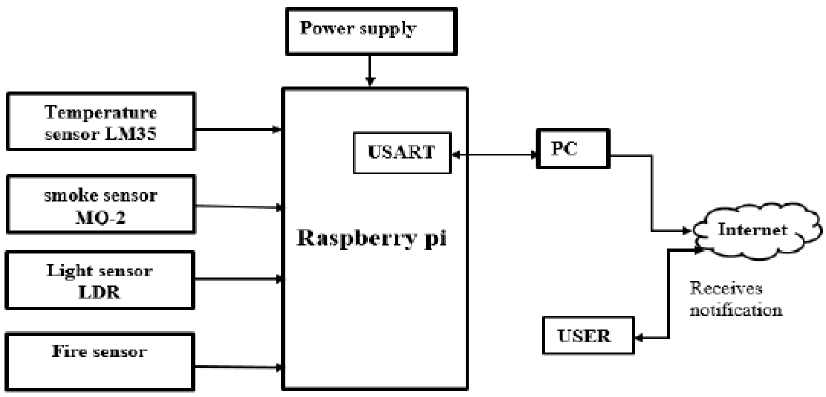


Figure 2.11: System architecture

The normal environmental condition is considered to set up the threshold value of various sensors. The output of the sensors and alarm generated are recorded in a database for future references., the designed system is an economically feasible solution to detect hazards in the buildings as it is constructed with a microcontroller and low-cost sensors [25].

In conclusion, the growth of the Internet of Things (IoT) and sensor-based networks aids in discovering various hazards in the buildings.

2.4.8 A Wireless Sensor Network for Fire Detection and Alarm System

Patrick Jason Y. Piera and Joseph Karl G. Salva (2019) highlighted that the conventional fire detection and alarm system (FDAS) is designed based on a wired transmission system that makes use of the controller area network (CAN) bus protocol. Nonetheless, the limited cable transmission distance of a conventional FDAS has shortcomings, such as high installation and maintenance costs, construction and expansion difficulties, corrosion, aesthetics, high fault rate, and high false alarm count [26].

To address these drawbacks, Patrick Jason Y. Piera and Joseph Karl G. Salva (2019) developed a wireless sensor network (WSN) based fire detection and alarm system. The overall system is shown in Figure 2.12. As a result, XBee is used as the wireless transceiver to communicate the fire detection node, fire alarm node, and fire alarm control panel. The mesh routing protocol of XBee allows the system to be more robust and flexible. The fire alarm control panel is a LabVIEW based program that utilises the state machine architecture which follows the detect-evaluate-store algorithm [26].

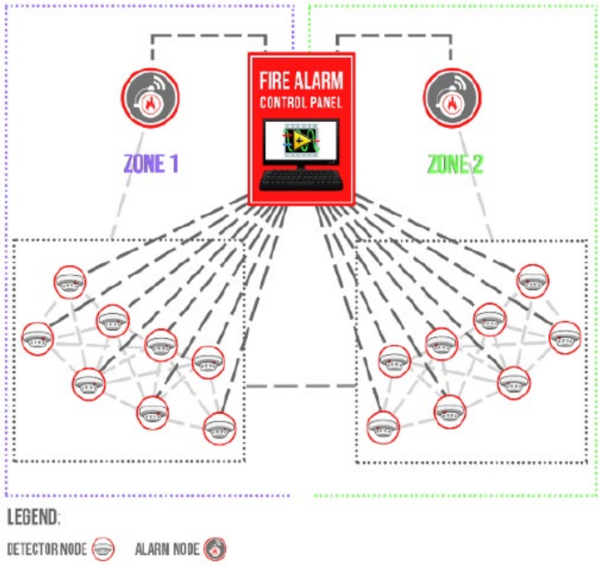


Figure 2.12: General structure of wireless fire detection and alarm system

In short, fire is a frequent and potent disaster that endangers human life and destroys the environment and properties. Thus, a fire detection and alarm system (FDAS) is necessary for multi-storey residential, commercial, and industrial buildings to avoid the development of an accidental fire to an uncontrollable outbreak. The utilisation of a wireless sensor network (WSN) increases the performance of the conventional wired FDAS.

2.4.9 IoT Enabled Smart Emergency LED Exit Sign Controller Design Using Arduino

Recent studies by Joonseok Jung et al. (2017) emphasised that the conventional emergency exit sign systems are not available to react to an altering dangerous environment or to get the immediate attention of occupants for exiting. Most occupants have difficulty in identifying and utilising the signage information. The passive nature of the conventional system design has caused casualties of preventable deaths in fire and other disasters [27].

As a solution, Joonseok et al. (2017) proposed an IoT based system design that can be added to the conventional emergency exit signs. The system is constructed with smart sensors (fire detector sensor, humidity sensor, smoke sensor, glass break sensor), Arduino microcontroller, alarm, LED path display and LED downlight, Zig Bee (Pro Bee ZS10) modules and personal computer (PC) monitors. Figure 2.13 depicts the architecture of the overall system design. The emergency exit signs are dynamic and depend on the real-time information from the sensors [27].

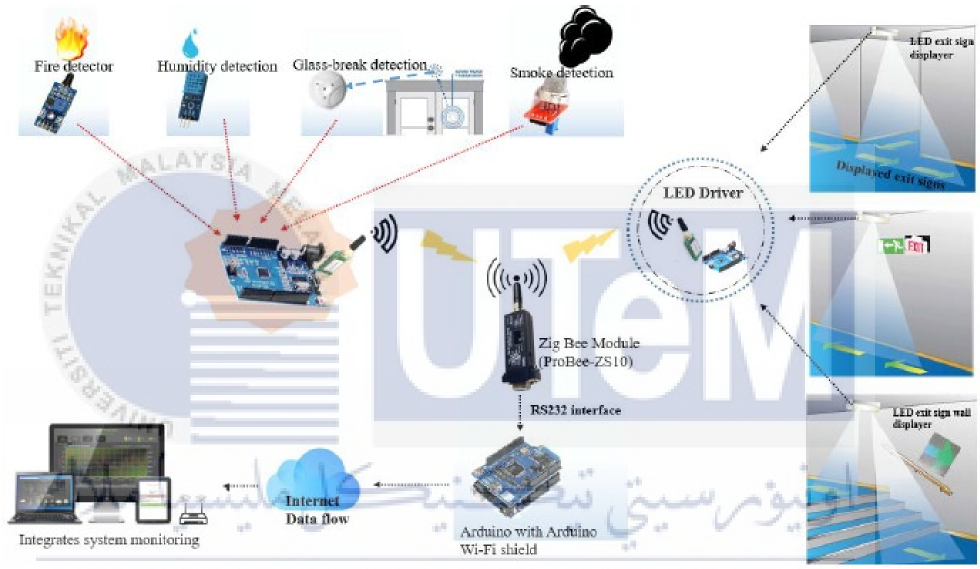


Figure 2.13: IoT enabled emergency LED exit sign, system design architecture

The implanted test verified that the optimum evacuation path to the safety presented from the controller was within 19 seconds. In brief, the IoT enabled smart emergency LED exit signs using Arduino is more sensitive, noticeable, and more effective in guiding occupants away from the harmful zone and can effectively direct them along the intended path. However, Zig Bee based module gateway devices used in the system can only operate in a short range of communication [27].

2.4.10 Development in Building Fire Detection and Evacuation System

Gajanand S. Birajdar et al. (2020) summarised the literature reviews associated with recent improvements in building fire detection and emergency evacuation system. The early detection of fire aids to prevent further consequences and saves the life of occupants. It is also vital to direct the building occupants to the safe emergency exit during a fire event [28].

The studies of Gajanand S. Birajdar et al. (2020) are intended to provide a systematic review of the details about fire simulation tools with features, suitable hardware, communication methods, and operative user interface. Table 2.1 compares hardware, fire sensing devices, simulation software, communication technology and user interface utilised by various researchers [28].

Table 2.1: Comparison of hardware, fire sensing devices, simulation software, communication technology and user interface

Source	Hardware/Technology	FireSensing Devices	Simulation Software	Communication Technology	User Interface
[1]	Raspberry Pi	LM 35Smoke SensorGas Sensor (MQ9)	FDS	GSM	No work on evacuation
[3]	nRF24L01 transceivers, Laptopwith Arduino	IR Flame Sensor	PythonMATLAB's roboticsPackage	RF transceivers	HTML/CSS based website
[5]	Ardunio	RFM23B RFID, LM35, HC-05,PIR Sensor	BIM	Bluetooth	Audio Signal, SMS on user mobile.
[4]	Mobile Phone with RFIDReader capability	RFID tags	Path Planner, Viewpoint Calculator, and MobiX3D	RFID technology	Mobile phone-based App
[7]	Mobile Phone with NFC and RFID reader	Active temperature and RFID sensor tags	MobiX3D, Viewpoint Calculator	RFID, Cloud Computing	Mobile Phone
[9]	FPGA, Microcontroller	Temperature Sensor	TimeNET	Wireless Transceiver	Direct Alarm System is provided at each floor
[12]	Zigbee, RFID	Temperature, Humidity, and Light	MySQL Database	WSN Technology	LCD Display
[17]	Microcontroller	Smoke	BAS(Building Automation System)	Cloud	App on Smartphone
[21]	IoT, Arduino	LM35, HC-05, PIR Sensor	BIM	Bluetooth, RF Communication	Audio Signal, SMS on user mobile.
[31]	Turtlebot2, Parrot AR. Drone 2.0& DJI Phantom 4	Illuminance sensor, Arduino Uno as a sensor	Google Map	Wireless	Application Mobile
[50]	IoT, Microcontroller	Temperature, CO, OpticalDensity Sensor	GIS, Matlab	wireless sensor Network	Fire Alarm, Emergency Lightening system

It consists of a multi-sensor module for detecting environmental parameters, such as heat, smoke, flame and gas with signal conditioning, amplifier circuit, processing unit, alarm system, and safe evacuation route display. Figure 2.14 illustrates the technologies of fire detection [28].

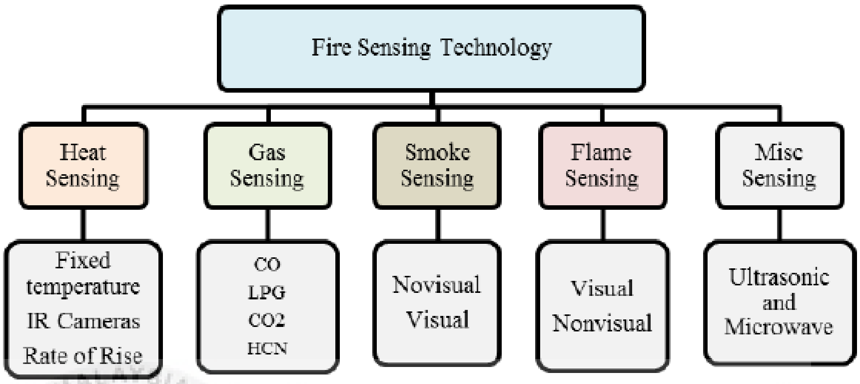


Figure 2.14: Fire sensing technologies

An effective hardware platform is responsible for processing further actions when a fire is detected. Figure 2.15 depicts the block diagram of the fire alarm system [28].

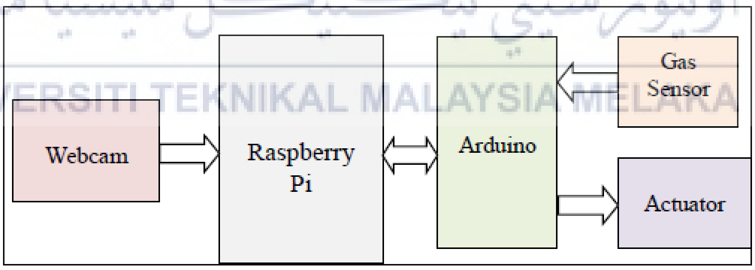


Figure 2.15: Block diagram of fire alarm system

The researchers use many hardware devices till now. Table 2.2 summarises the details of the hardware platform [28].

Table 2.2: Comparison of hardware platform

Hardware	Response time	Language Supported	Cost	Onboard Storage	Multi Programming	I/Os (Approx.)
Arduino Board	Comparatively Slow	C/C++	Low Cost	Available	Not Possible	13
Raspberry Pi	Faster than Arduino	C, C++, Python, ruby	Expensive	Need SD Card	Possible	40
FPGA	Faster	VHDL	Expensive	Available	Possible	500
DSP	Fast real-time computation	C++, C, JAVA, JavaScript, LLVM bit code	Expensive	Need External Memory	Possible	110

Sensors act as the end devices to collect the environmental parameters for the early discovery of fire. An appropriate type of network is needed to connect the sensors for smooth communication among each other. The desired communication technology by various researchers is shown in Table 2.3 [28].

Table 2.3: Comparison of communication technology used in fire detection

Hardware	ZigBee	RFID	Bluetooth	WiFi
IEEE Spec.	802.15.4	--	802.15.1	802.11 a/b/g
Frequency (MHz)	868-868.2	433, 860-960	2402-2482	2400-2500
Range (m)	100+	Upto 100	10	10-100
Power consumption	Very Low	Varies with frequency	Medium	High
Data Speed	250 Kbps	640 kbps	1 Mbps	54 Mbps
Network Topology	Mesh	Point-to-Point	Point-to-Point	Star
Security	Highly secure 128-bit AES-based encryption system	Hardware and Protocol Level	Protocol Level	WPA, WEP, etc.

In a nutshell, the project "An Automated Illuminated Emergency Exit Door System" which can direct occupants based on real-time situations is necessary. This is because occupants who are caught inside the building need to evacuate through a safe emergency exit route. Still, the conventional fire exit routes may direct the occupants to the wrong exit as fire spreads in any direction.

CHAPTER 3

METHODOLOGY

This chapter describes the method adopted in the development of the complete Auto IEED system. It covers every hardware and software used in this project.

3.1 Life Cycle of Project Development

The work of this project is generally broken down into four core phases: research phase, designing phase, development phase and analysis phase, as illustrated in Figure 3.1.

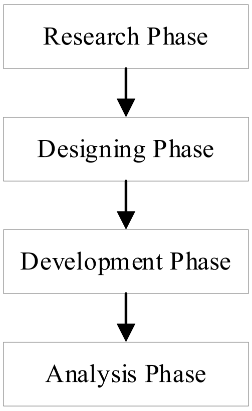


Figure 3.1: Core development phase of Auto IEED system

The emergency exit door system mentioned in this thesis consists of two modules, such as hardware and software. Both modules are responsible for the functionality and effectivity of the system. Early planning is crucial in designing and developing the system. Figure 3.2 depicts the related phases for the development of the Auto IEED system.

The first core phase is concerned with the literature studies and research of the system. It includes the identification of problems. The objectives are established by observations and knowledge gathered from online sources, articles, journals and books. Moreover, the evaluation of the previous projects developed is included. In this phase, the planning and schedule that matched the selected development approach were determined. The scopes, specifications and Gantt chart were completed at the end of this phase.

Designing is the second core phase of system development. The needs and analysis attained from the previous phase are translated into the design specifications of the system. It also includes the hardware design, which is a critical job. The hardware design involves a microcontroller and fire detectors. The fire detectors are a smoke sensor, infrared (IR) flame sensor, temperature and humidity sensor. If all of the input fire detectors are activated, the former is the control unit that determines the presence and location of the fire. In this case, a push notification will be delivered, a buzzer will sound, and the LED strips will flash to instruct the people to leave the buildings.

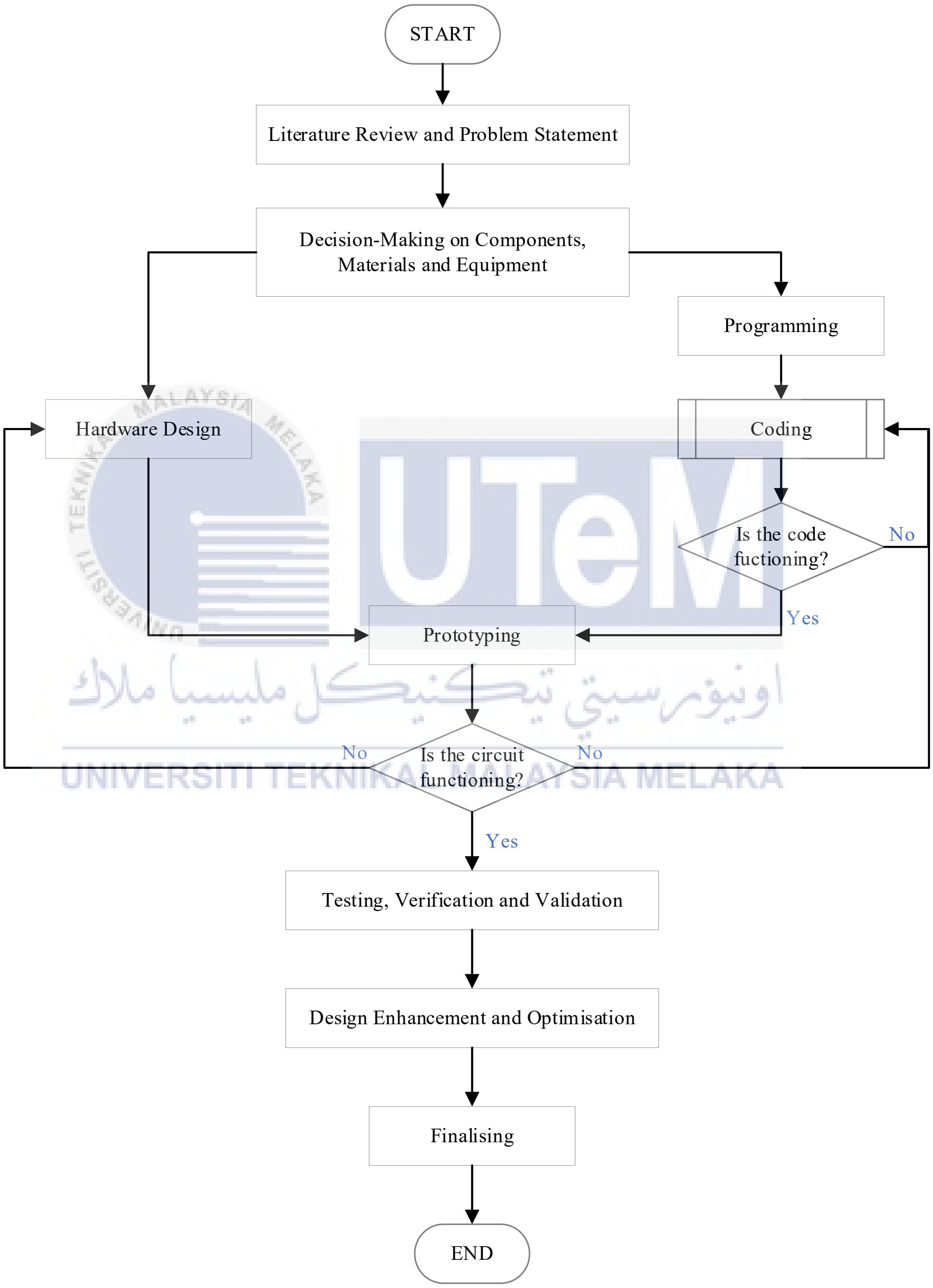


Figure 3.2: Related development phase of Auto IEED system

Development is the third core phase of system development. It includes writing the program in the preferable C language for the selected microcontroller. Simulation is the best method to validate the system design. A solderless breadboard was used to assemble the system, and the printed circuit board (PCB) layout was designed after the testing on the general-purpose board was completed. The final assembly of the system was carried out on the designed PCB, and it was ready to test for the desired output. The system is now prepared for the final phase (analysis phase) of system development.

3.2 Overview of Project

The Auto IEED system consists of four major elements: power supply unit, control and processing unit, alerting and indicating unit, and detector. The electronic components that can represent a real-life system were selected and used in this system, as listed in Table 3.1. Figure 3.3 shows the block diagram of the system.

Table 3.1: Components of Auto IEED system

Element	Component
Power Supply Unit	18650 Li-Ion Battery
Control and Processing Unit	NodeMCU ESP32
Alerting and Indicating Unit	Piezo Buzzer, SK6812 LEDs
Temperature Detector	DHT11 Temperature and Humidity Sensor
Smoke Detector	MQ-2 Gas/Smoke Sensor
Flame Detector	KY-026 Flame Sensor
Wireless Control and Communication	ThingSpeak, Pushover

The detector system was constructed by the integration of DHT11 temperature and humidity sensor, MQ-2 gas/smoke sensor and KY-026 flame sensor with NodeMCU ESP32 microcontroller. The alerting and indicating unit was constructed by the integration of piezo buzzer and SK6812 LEDs with NodeMCU ESP32 microcontroller. The microcontroller plays a vital role in acquiring the readings from sensors and triggering the piezo buzzer and LEDs. The data collected from the sensors were uploaded to the ThingSpeak IoT platform by NodeMCU ESP32 via a wireless network protocol. The data collected were stored and monitored on the cloud in real-time. NodeMCU ESP32 conducted appropriate responses according to the data input received. The flow of the system will be further explained in Section 3.6.

Suppose that a fire is caught in a multi-story building and the data collected from the sensors exceed the threshold level set. In that case, a push notification message will be sent to the registered mobile device of the occupants using the Pushover application. Meanwhile, the occupants can track the indication of LEDs on the emergency exit door to evacuate the building correspondingly. The rescue teams can also utilise the indicator to locate the site of the fire.

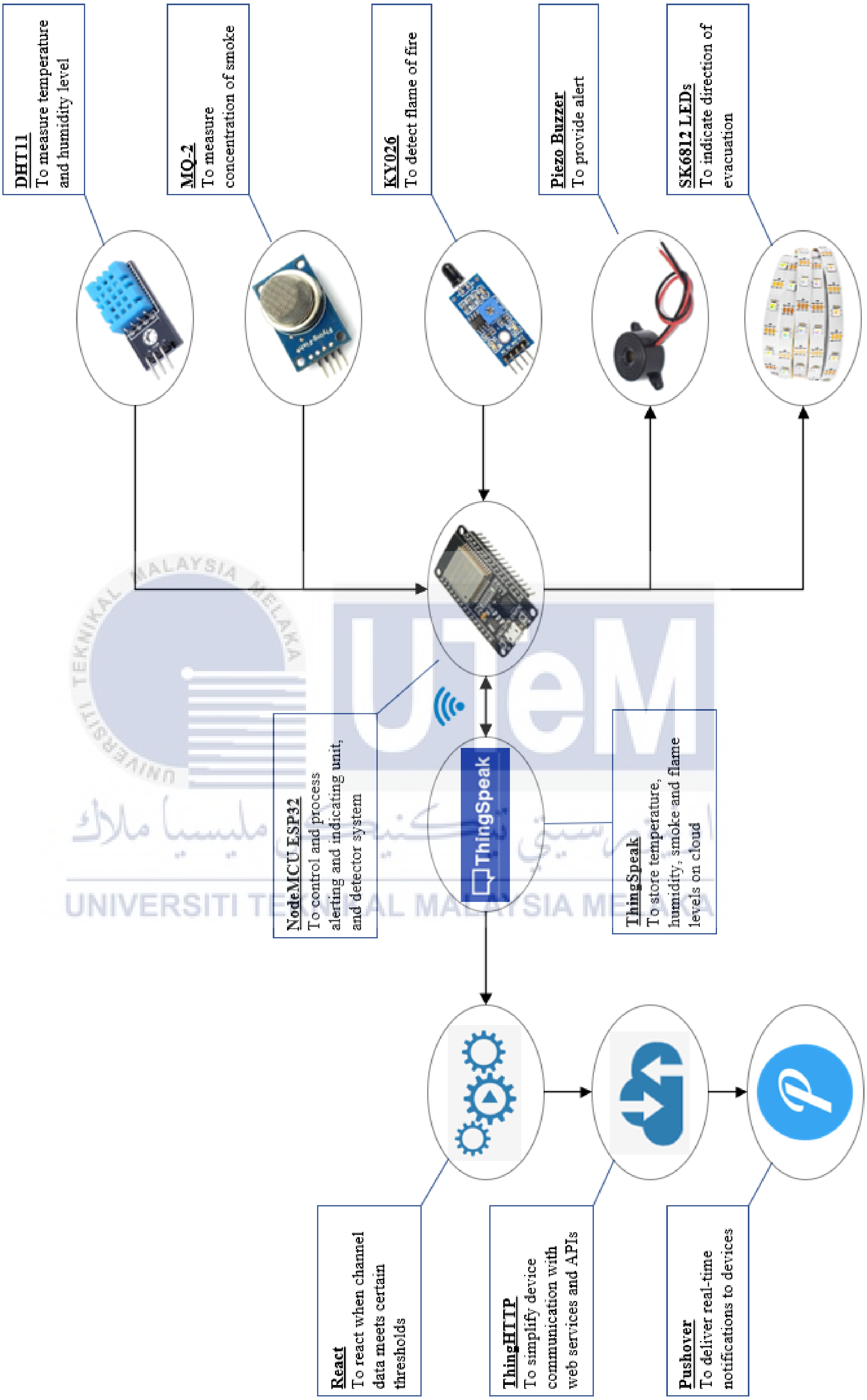


Figure 3.3: Block diagram of Auto IEED system

3.3 Description of Hardware

The hardware used in the development of Auto IEED system is discussed in the following subsections.

3.3.1 NodeMCU ESP32

As stated in Section 3.2, NodeMCU ESP32 was used as the main control and processing unit of the system. It allows for fast prototyping through easy programming via Arduino IDE and the breadboard compatible construction. The parts of NodeMCU ESP32 are shown in Figure 3.4.

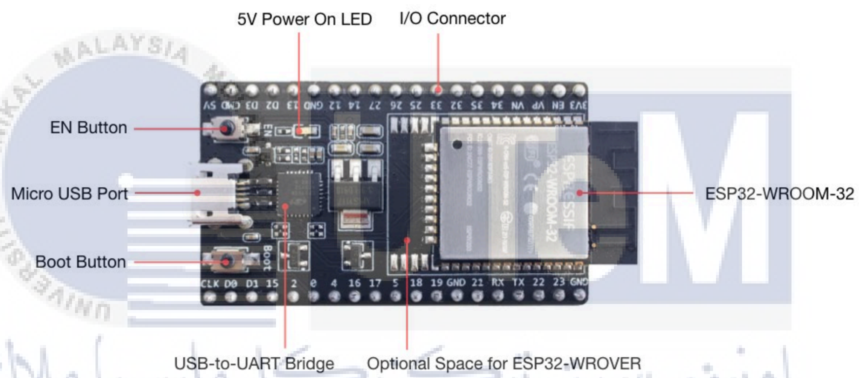


Figure 3.4: NodeMCU ESP32

NodeMCU ESP32 has 2.4 GHz dual-mode Wi-Fi and Bluetooth chips by TSMC 40 nm low power technology and radio frequency (RF) properties. In other words, it is safe, reliable and scalable to a variety of applications. The ESP32 has more functional GPIOs compared to the ESP8266. The multiplexing feature of the ESP32 chip permits the allocation of multiple functions to a single pin. Figure 3.5 depicts the pin location of NodeMCU ESP32.

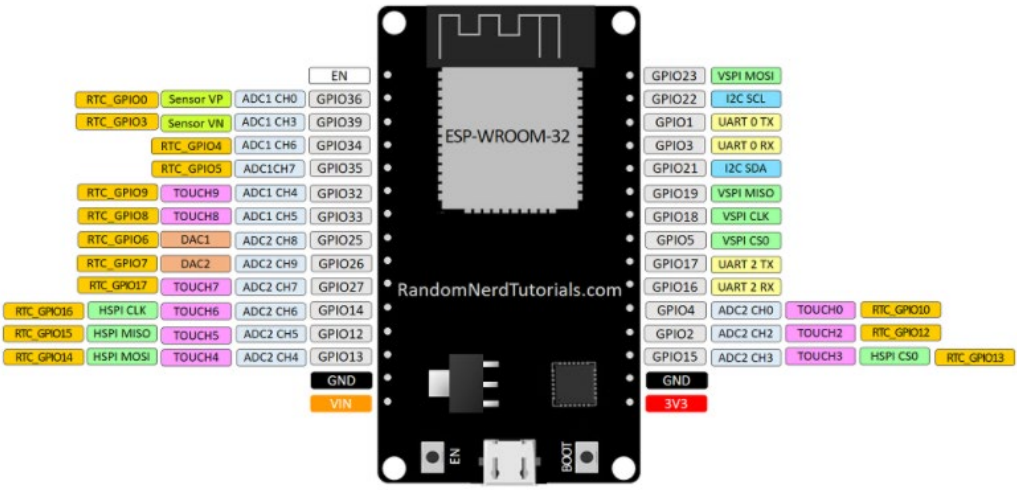


Figure 3.5: Pinout of NodeMCU ESP32

In the system, NodeMCU ESP32 was used to obtain data from the sensors and upload it to the ThingSpeak platform for storing and monitoring in real-time. It was used to trigger the alerting and indicating unit when the data meets certain conditions.

3.3.2 DHT11 Temperature and Humidity Sensor

In the system, DHT11 was used to measure the temperature and relative humidity of the surroundings. The readings obtained were uploaded and stored in the ThingSpeak platform by NodeMCU ESP32. DHT11 is an intuitive sensor because it consists of a chip that performs analogue to digital conversion of the temperature and humidity.

Table 3.2 shows the crucial specifications of the DHT11. It is on a breakout board with only three pins, as depicted in Figure 3.6.

Figure 3.6: Pinout of DHT11

DHT11 and DHT22 are very identical. DHT11 has a poorer resolution and a smaller measurement range of temperature and humidity. However, it is a bit cheaper than DHT22, and the sensor readings can be requested for every second.

Table 3.2: Specifications of DHT11

Specification	
Operating Voltage	3 – 5.5 V_{DC}
Operating Current	0.5 – 2.5 mA
Temperature Range	0 – 50 ºC ± 2 ºC
Humidity Range	20 – 90 % ± 5 %
Resolution	Temperature: 1 ºC Humidity : 1 %
Sampling Period	1 second

3.3.3 MQ-2 Gas / Smoke Sensor

In the system, MQ-2 was used to measure the smoke concentration in the air. The potentiometer was turned to adjust its sensitivity. The readings obtained were uploaded and stored in the ThingSpeak platform by NodeMCU ESP32. The detection of gas concentration is based on the varying resistance level of the sensing material. Table 3.3 shows the specifications of MQ-2 gas sensor.

Table 3.3: Specifications of MQ-2

Specification	
Operating Voltage	4.5 – 5 V_{DC}
Concentration	300 – 10,000 ppm
Power Consumption	<800 mW
Preheat Duration	2 minutes

The analogue output voltage depends on the concentration of gas/smoke. The greater the gas concentration, the higher the output voltage, and vice versa. The pinout of MQ-2 gas/smoke sensor is illustrated in Figure 3.7.

Figure 3.7: Pinout of MQ-2

3.3.4 KY-026 Flame Sensor

A burning flame will produce heat and emit IR rays that are not visible to human eyes. Thus, KY-026 was used to detect the presence of a fire. The potentiometer was turned to adjust its sensitivity. The readings obtained were uploaded and stored in the ThingSpeak platform by NodeMCU ESP32. The flame sensor module is integrated with a photodiode (IR receiver), resistor, capacitor, potentiometer and LM393 comparator on a circuit, as shown in Figure 3.8. It is based on the YG1006 sensor, which is a high speed and sensitive NPN silicon phototransistor. Table 3.4 describes the specifications of KY-026 flame sensor.

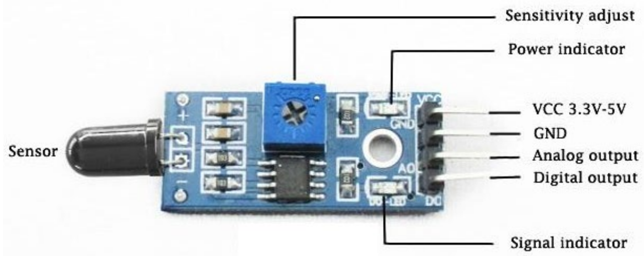


Figure 3.8: KY-026 flame sensor module

Table 3.4: Specifications of KY-026

Specification	
Operating Voltage	3.3 – 5 V_{DC}
Infrared Radiation Sensitivity	700 – 1000 nm
Detection Angle	0 – 60°

3.3.5 Piezo Buzzer

In the system, piezo buzzer was used to provide alert when a fire occurs. It is a passive component terminated with red and black wires, as shown in Figure 3.9. The operating voltage is around 5 V_{DC}.

Figure 3.9: Piezo buzzer

3.3.6 SK6812 Light-Emitting Diodes (LEDs)

IP64 type of strip, as shown in Figure 3.10, was used in the system. It has less protection from the environment. However, it is easy to cut into smaller pieces and mount to any surface with its available sticky back. SK6812 LEDs were used to provide indication on the emergency exit doors and guide the building occupants in an evacuation. The current consumed by SK6812 depends on the colour and brightness of each LED. If only one of the three colours is on, it will use less power. If the pixel is set to white, it will use maximum power. It is essential to use a 5 V_{DC} power supply.

Figure 3.10: SK6812 IP64 LEDs

3.3.7 18650 Li-Ion Battery

18650 lithium-ion batteries, as depicted in Figure 3.11, were used as the power supply of the system. “18650” is based on its size: 18 mm x 65 mm. It is a high drain battery that provides a large amount of current than the standard batteries. It typically takes about 3 hours to be fully charged.

Figure 3.11: 18650 Li-ion batteries

3.3.8 LM7805 Integrated Circuit (IC)

LM7805, as illustrated in Figure 3.12, was used to build a +5 V voltage regulator circuit in the system. It provides a constant +5 V output voltage for a 7.4 V input voltage from the 18650 Li-ion batteries. The designation of 7805 implies two meanings, such as “78” is a positive voltage regulator and “05” is an output voltage of 5 V. The output current can rise to 1.5 A. However, the IC is suffered from heavy heat loss, so a heat sink was used.

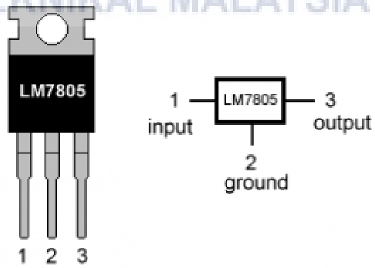


Figure 3.12: Pinout of LM7805

3.3.9 Electrolytic Capacitors

Both 10 μF and 100 μF of electrolytic capacitors were used to construct a +5 V voltage regulator circuit in the system. The design of the circuit will be further explained in Section 3.5. An electrolytic capacitor is a polarised capacitor that employs an electrolyte to obtain a higher capacitance than other capacitor types. The voltage on the positive (+) terminal should always be larger than the negative (-) terminal. Therefore, an electrolytic capacitor is used only in DC circuits. Figure 3.13 shows the pinout of an electrolytic capacitor.

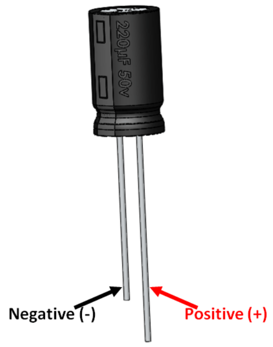


Figure 3.13: Pinout of electrolytic capacitor

3.4 Description of Software

The software used in the development of Auto IEED system is discussed in the following subsections.

3.4.1 Arduino IDE

In this project, Arduino Integrated Development Environment (IDE), as presented in Figure 3.14, was used to write, compile and upload programs into the NodeMCU ESP32 board. It is open-source software available for operating systems, such as Windows. The IDE environment consists of two essential parts: Editor and Compiler. Editor was used to write the needed program, whereas Compiler was used to upload the program into the board. Arduino IDE supports both C and C++ programming languages.

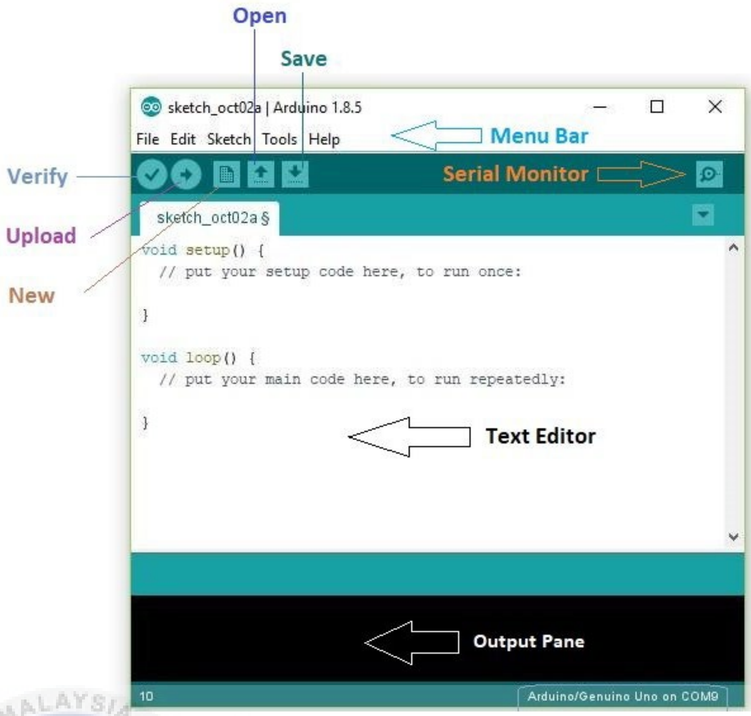


Figure 3.14: Introduction to Arduino IDE

3.4.2 NI Multisim

In this project, NI Multisim was used to design, construct, and simulate the +5 V voltage regulator circuit. The use of NI Multisim allows the behaviour of the voltage regulator circuit to be instantaneously visualised and analysed. It helps to reduce the iterations of printed circuit board (PCB) prototype and save the cost of development.

3.4.3 Proteus Design Suite

In this project, Proteus was used to design the circuit of Auto IEED system on a printed circuit board (PCB). The use of Proteus allows this project to be cost-effective and contains fewer errors because of the schematic construction of the circuit on it.

3.4.4 ThingSpeak

In this project, ThingSpeak was used to retrieve, store and monitor data from the sensors over the Internet. It provides immediate visualisations of the data. In ThingSpeak, ThingHTTP application was established to configure the content of the messages and trigger a push notification if the data exceeds a certain threshold. The notification is sent to the mobile device via Pushover.

3.4.4.1 Configuration of ThingSpeak Channels

To log the data, four new ThingSpeak channels, as presented in Figure 3.15, were created to hold the readings in this project. Each channel was created with four fields: Temperature (ºC), Humidity (%), Smoke Concentration (ppm) and Fire Class, as shown in Figure 3.16. Then, the *Save Channel* button was hit.

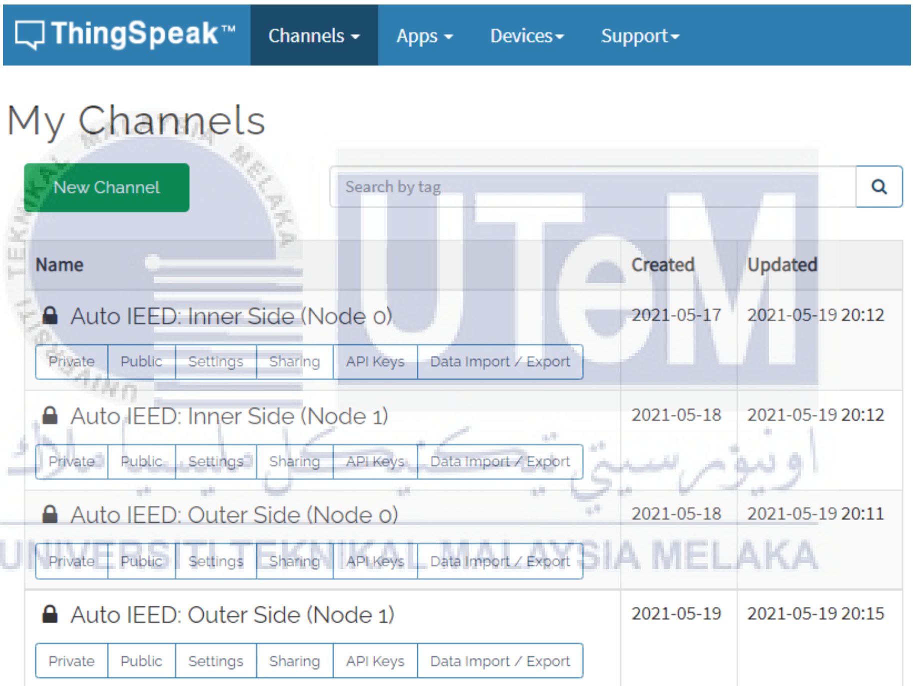


Figure 3.15: Creation of ThingSpeak channels

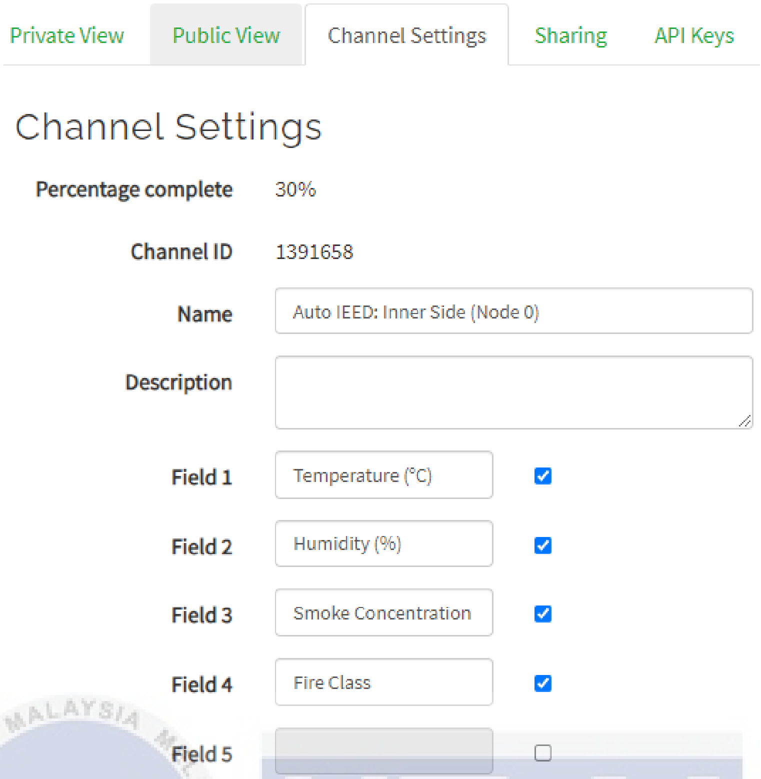


Figure 3.16 (a): Channel settings of node 0 at inner side

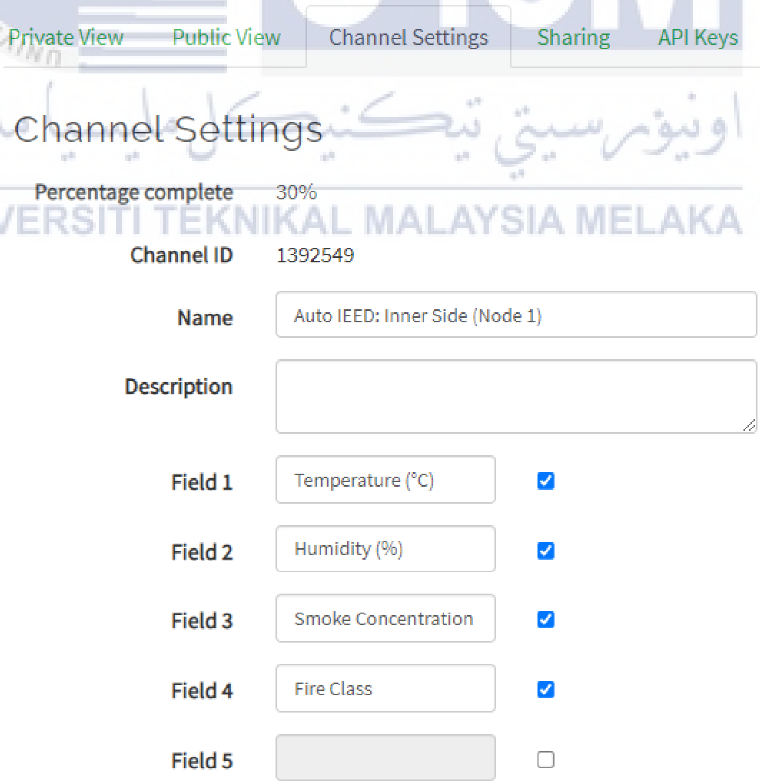


Figure 3.16 (b): Channel settings of node 1 at inner side

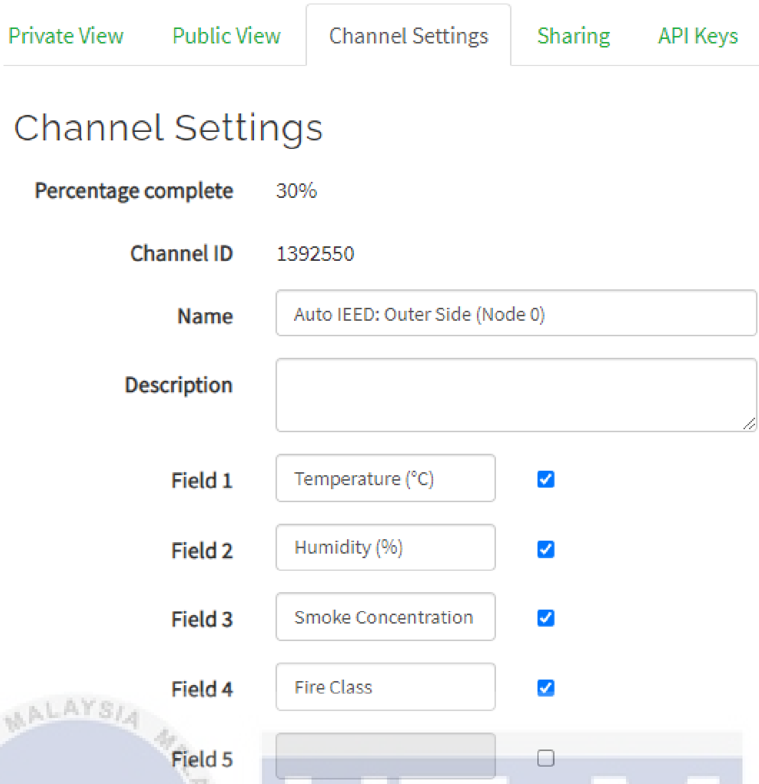


Figure 3.16 (c): Channel settings of node 0 at outer side

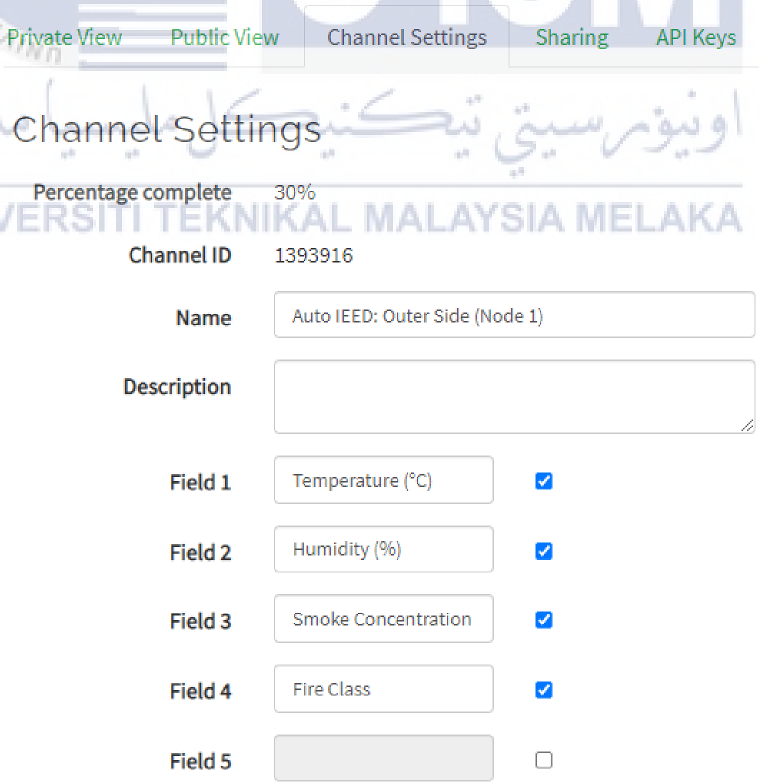


Figure 3.16 (d): Channel settings of node 1 at outer side

3.4.4.2 Configuration of ThingHTTP Application in ThingSpeak

ThingHTTP was used to trigger and send the message on HTTP to Pushover, which in turn was delivered to the mobile device. In this project, two new ThingHTTPs were created, as presented in Figure 3.17, and the configuration of the ThingHTTPs is shown in Figure 3.18. The Pushover's *User Key* and *API Token/Key* and the content of messages were included in the *Body* section. Then, the *Save ThingHTTP* button was hit.

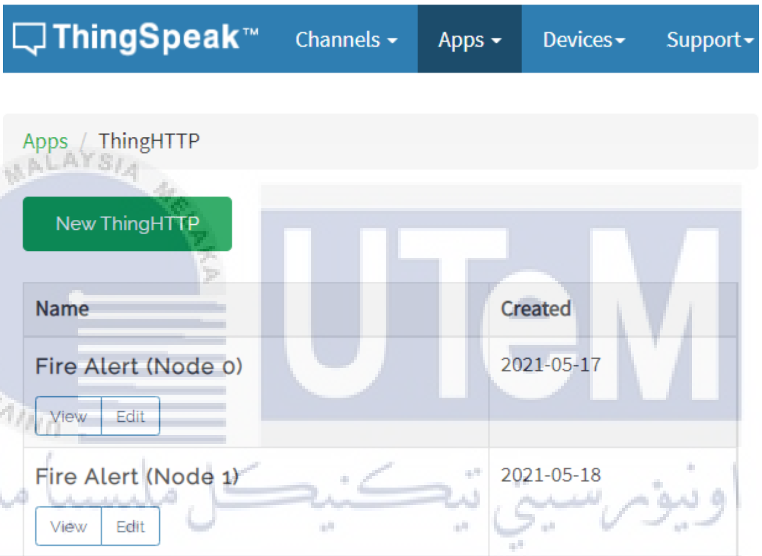


Figure 3.17: Creation of ThingHTTPs in ThingSpeak

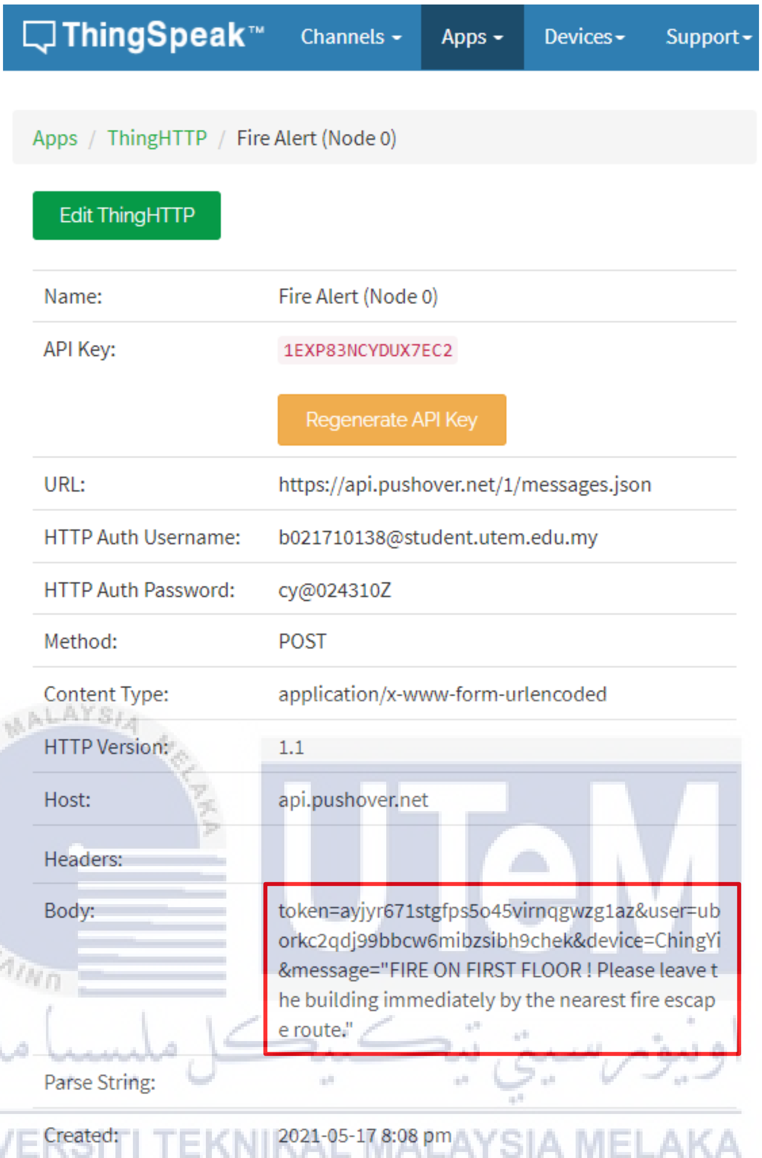


Figure 3.18 (a): Configuration of ThingHTTP for node 0

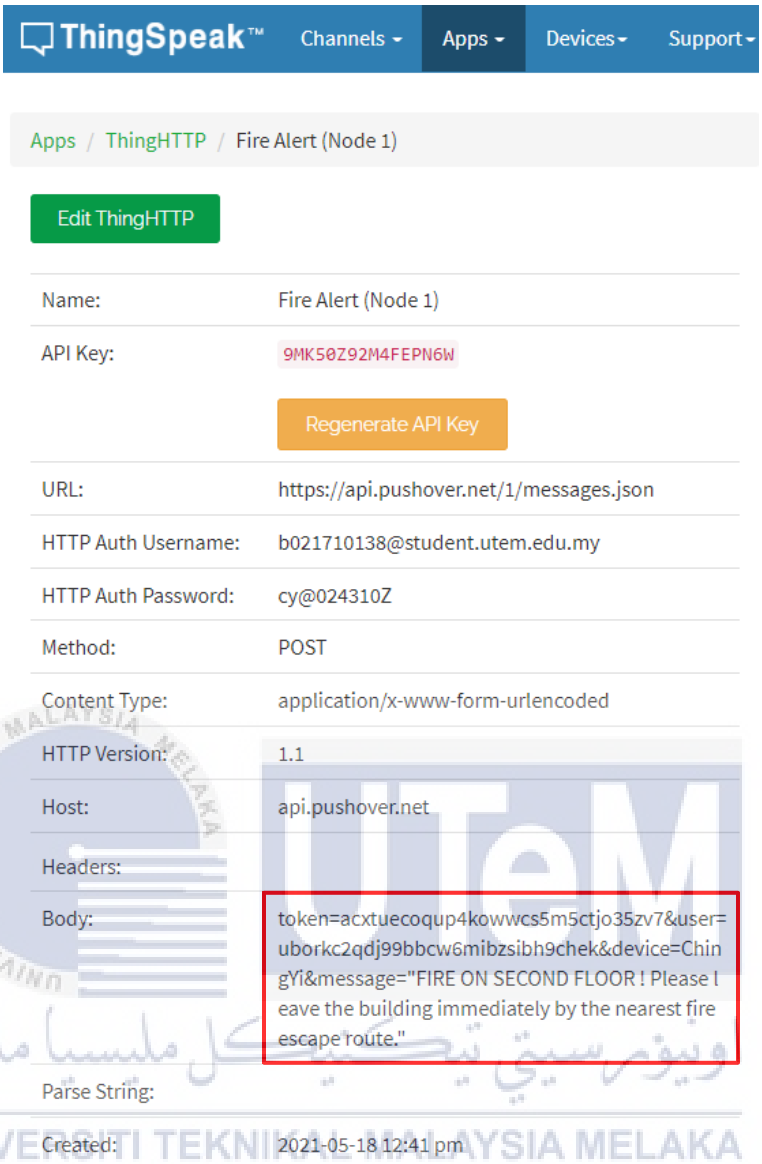


Figure 3.18 (b): Configuration of ThingHTTP for node 1

3.4.5 Pushover

In this project, Pushover was used to receive unlimited real-time push notifications on the registered mobile devices. It is compatible with Android, iOS and desktop browsers.

3.4.5.1 Configuration of Pushover Application on Mobile

A Pushover account was signed up on the desktop, and a unique *Your User Key* was provided. The device to receive the notifications was added under *Your Devices*.

Next, two applications were created for node 0 and node 1 respectively in *Your Applications*. The overview page of Pushover is shown in Figure 3.19. Once the applications were created, each application has its unique *API Token/Key* for sending notifications, as presented in Figure 3.20.

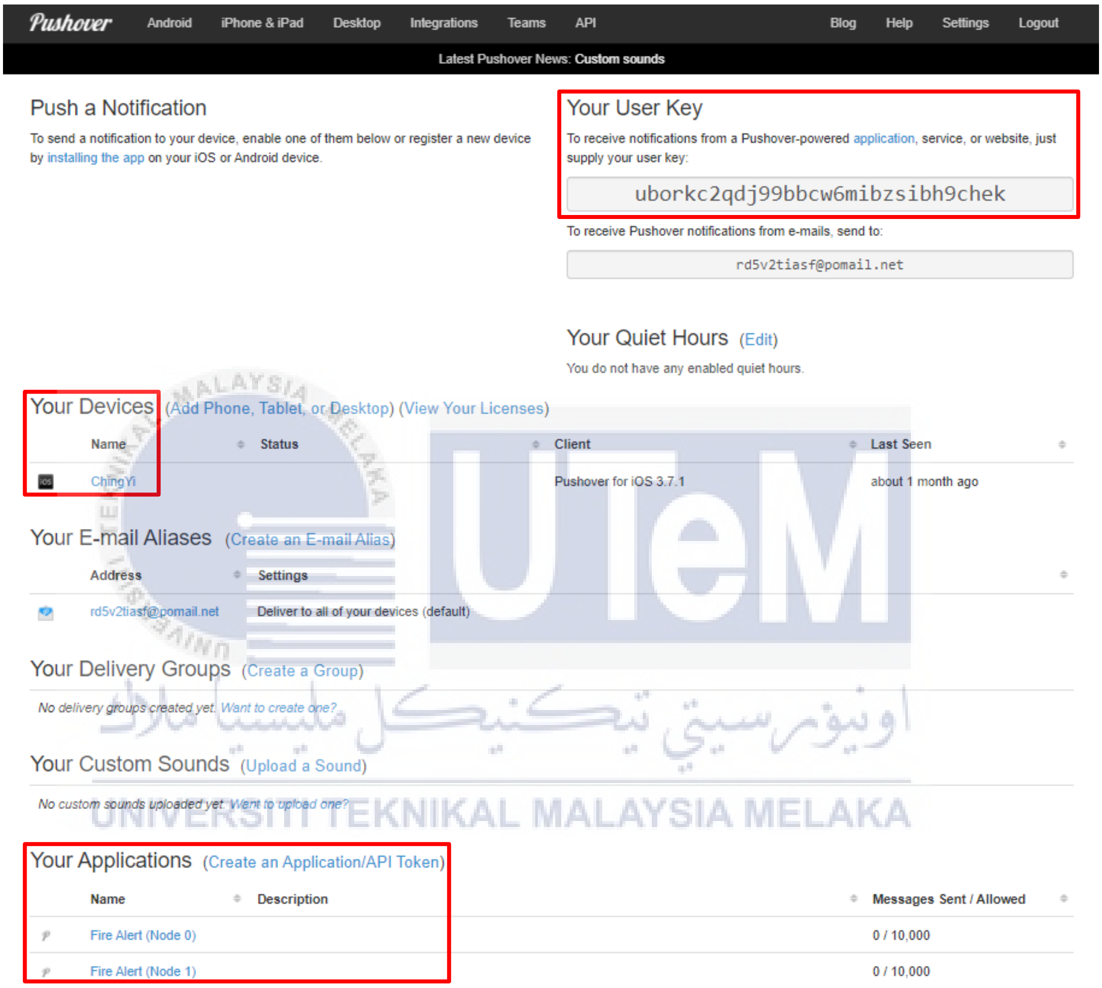


Figure 3.19: Overview page of Pushover

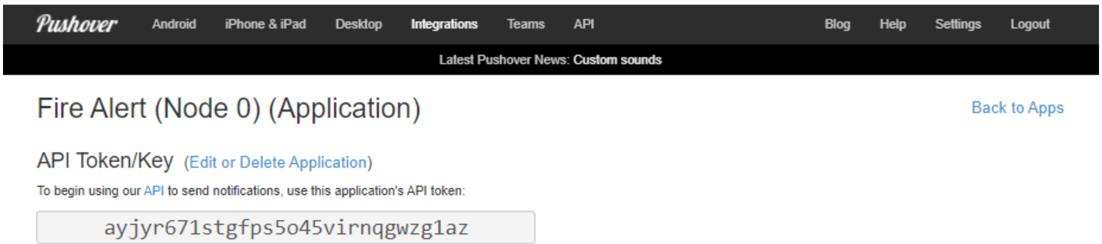


Figure 3.20 (a): API token/key for node 0

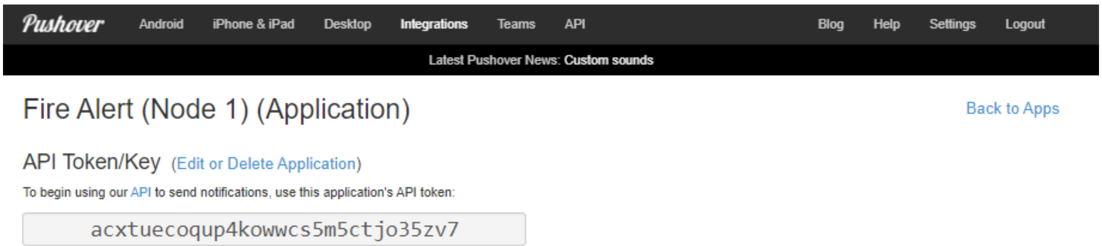


Figure 3.20 (b): API token/key for node 1

3.4.6 Lux Light Meter Pro

A light meter is an instrument for measuring light. In this project, Lux Light Meter Pro was used to measure the amount of light in the surroundings of Auto IEED system. It is an easy-to-use and functional light intensity (lux) meter. However, it works to the limits of the smartphone. Lux Light Meter Pro gives identical information from a given surrounding comparable to other handheld light meter devices. Its accuracy is typically within a 1/10 stop of standalone devices.

3.4.6.1 Luminosity Measurement of Auto IEED System

The luminosity of the red and green LEDs used in the system was measured at different distances with a constant height of 60 cm from the floor. The setup of the experiment is shown in Figure 3.21. Based on Figure 3.21, a measuring tape was used to identify the distances from the installed system, and a tripod stand was used to hold the smartphone (iPhone 11). The experiment was carried out in a dark room to avoid light interference from other sources and led to the wrong measurement of luminosity. Three readings were taken for each distance.

Figure 3.21 (a): Luminosity measurement of red LEDs

Figure 3.21 (b): Luminosity measurement of green LEDs

3.5 Circuit Design

The circuit designs of the 5 V voltage regulator and the complete Auto IEED system are discussed in the following subsections.

3.5.1 5 V Voltage Regulator

The implementation of the Auto IEED system required a constant 5 V input voltage to supply the alerting and indicating unit and detector system. Hence, LM7805 which is a transformer IC was used. It offers linear voltage regulation and conversion. The digits "05" of LM7805 IC indicates the value of the output voltage regulated. The 7.4

V to 5 V voltage regulator was constructed, tested and verified using Multisim, as shown in Figure 3.22. Figure 3.23 presents the simulation result of the regulated output voltage. It can generate an identical amount of output current as applied at the input end. The uniqueness of this circuit is mandatory for SK6812 LEDs which require a large amount of current for operation. The voltage drop of 2.4 V is dissipated as heat. Therefore, a heatsink was used to protect the IC from being fried.

100 µF and 10 µF are input and output decoupling capacitors for the LM7805 voltage regulator. They are used to provide a low-impedance and high-frequency path at both ends of the regulator. They are required to suppress the high-frequency noise from the source and the load to avoid bounce on the regulated output voltage. The 10 µF output capacitor is also needed for frequency compensation of the LM7805 IC. The value of both the capacitors was recommended by the manufacturer.

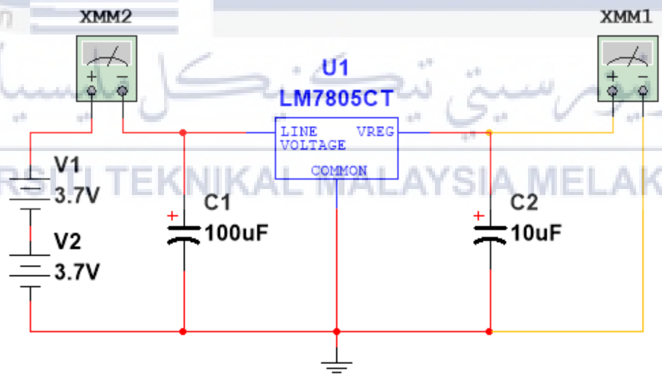


Figure 3.22: Schematic diagram of 5 V voltage regulator

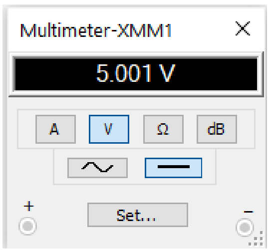


Figure 3.23: Output voltage of 5 V voltage regulator

3.5.2 Auto IEED System

The circuit connection of the complete Auto IEED system is depicted in Figure 3.24. It is an integration of the 5 V voltage regulator, power supply unit, control and processing unit, alerting and indicating unit, and detector system.

Table 3.5 lists the pin connections of the system. In real life application, this project is designed to be implemented at the exit of an exit route of a multi-story building. Thus, the Auto IEED system is intended to be installed at both sides of an emergency exit door on each level.

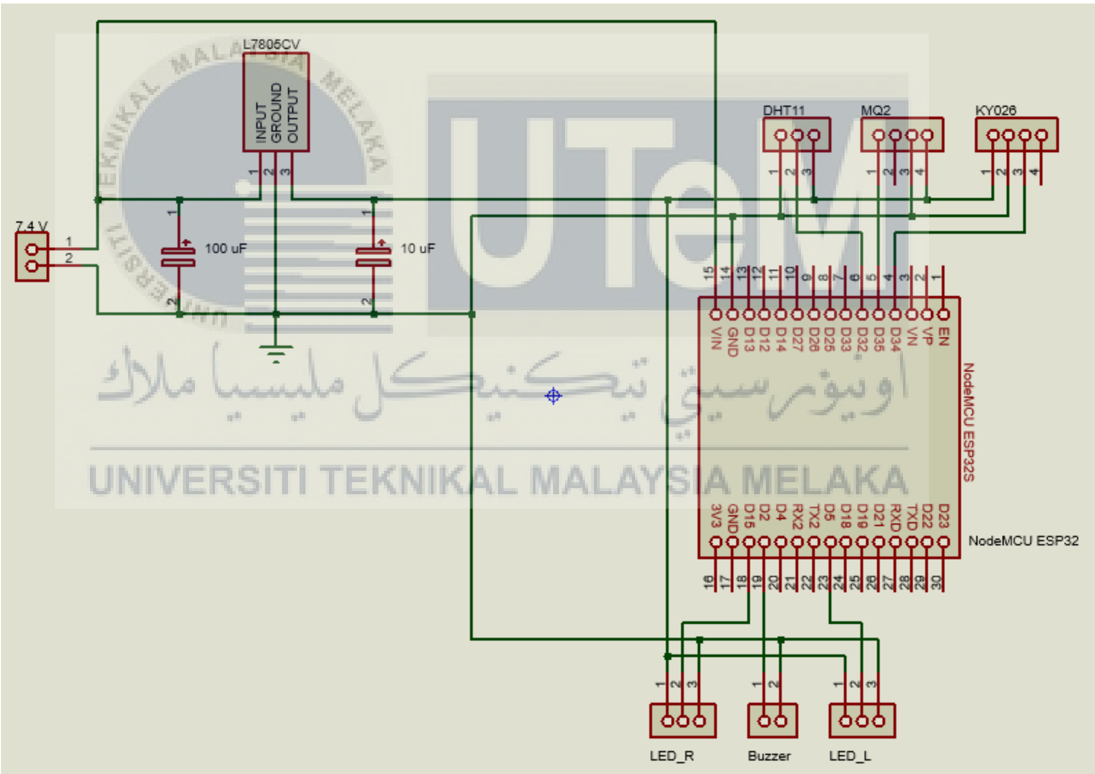


Figure 3.24: Schematic diagram of Auto IEED system

Table 3.5: Pin connection of Auto IEED system

Component	Pin of Component	Pin of NodeMCU ESP32
DHT11 Temperature and Humidity Sensor	Vcc	-
	Data	GPIO 32
	Ground	Ground
MQ-2 Gas/Smoke Sensor	Vcc	-
	Ground	Ground
	Digital Out	-
	Analog Out	GPIO 35
KY-026 Flame Sensor	Digital Out	GPIO 34
	Vcc	-
	Ground	Ground
	Analog Out	-
Piezo Buzzer	Positive (+)	GPIO 2
	Negative (-)	Ground
SK6812 LEDs: Left	Vcc	-
	Data	GPIO 5
	Ground	Ground
SK6812 LEDs: Right	Vcc	-
	Data	GPIO 15
	Ground	Ground
18650 Li-Ion Battery	Positive (+)	Vin
	Negative (-)	Ground

3.6 Flow Chart

In practice, this project is intended to be executed at the exit of an escape path of a multi-story building. Hence, the Auto IEED system is designed to be mounted on both sides of an emergency exit door on each level. A number of two levels or layers were used in the execution of this project. As a result, there were be four Auto IEED systems mounted in the multi-story building. Assume that the section facing the staircase is the outer side, and the section facing the interior of the building is the inner side. The installation of an Auto IEED system was such that its SK6812 LEDs were on the opposite side. The flowcharts of the algorithm used at the inner side of both the lower layer (node 0) and the upper layer (node 1) are illustrated in Figure 3.25 and Figure 3.26 respectively.

The algorithm at the outer side of the emergency exit door is written based on the fire conditions on both the lower layer (node 0) and the upper layer (node 1), as depicted in Figure 3.27 and Figure 3.28 correspondingly. The nodeMCU ESP32 is subscribed to the ThingSpeak channel of another layer. It continually monitors the readings published to that channel and toggles the upper part and lower part of LEDs mounted on the emergency exit door.

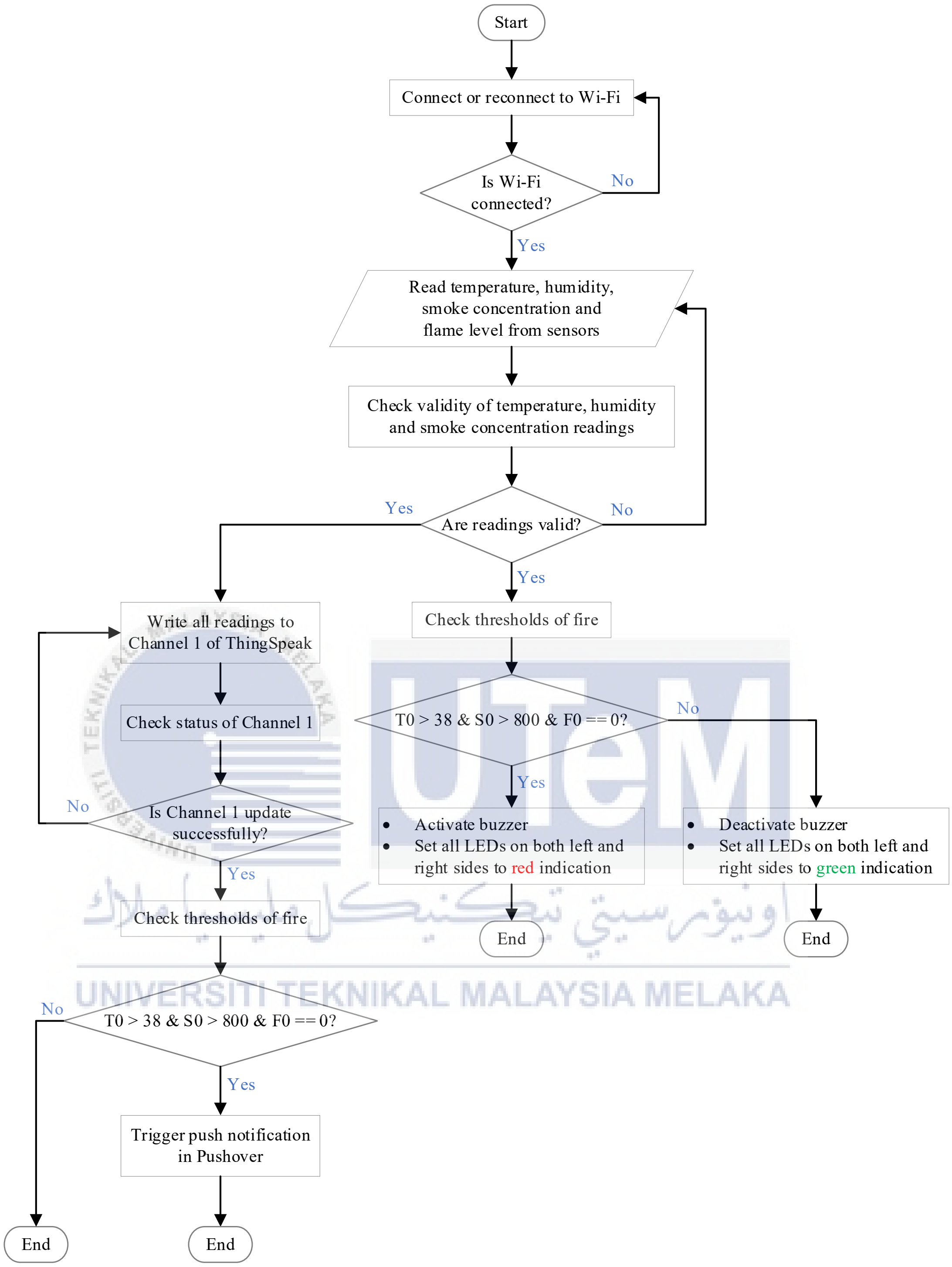


Figure 3.25: Flowchart of node 0 at inner side

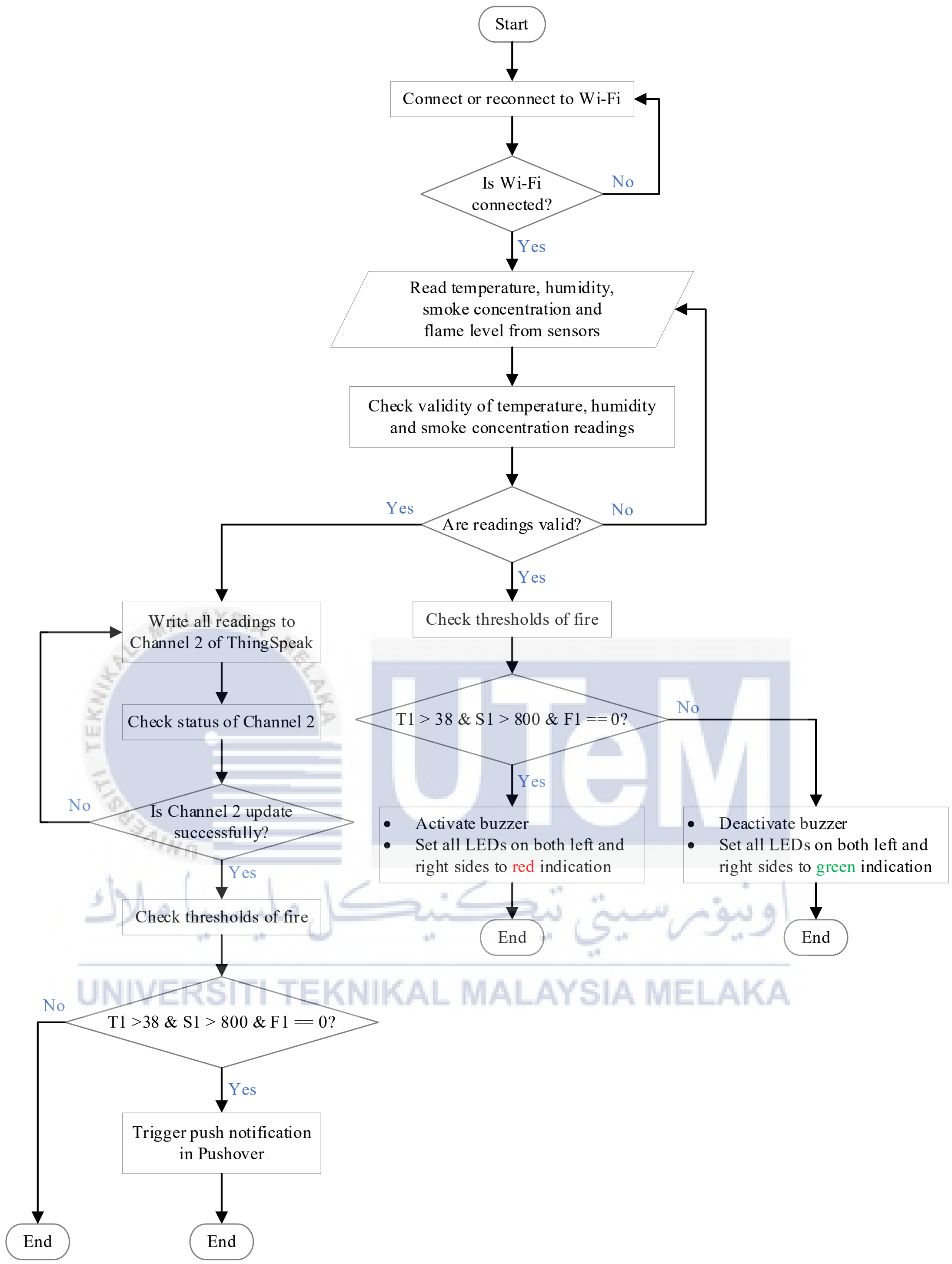


Figure 3.26: Flowchart of node 1 at inner side

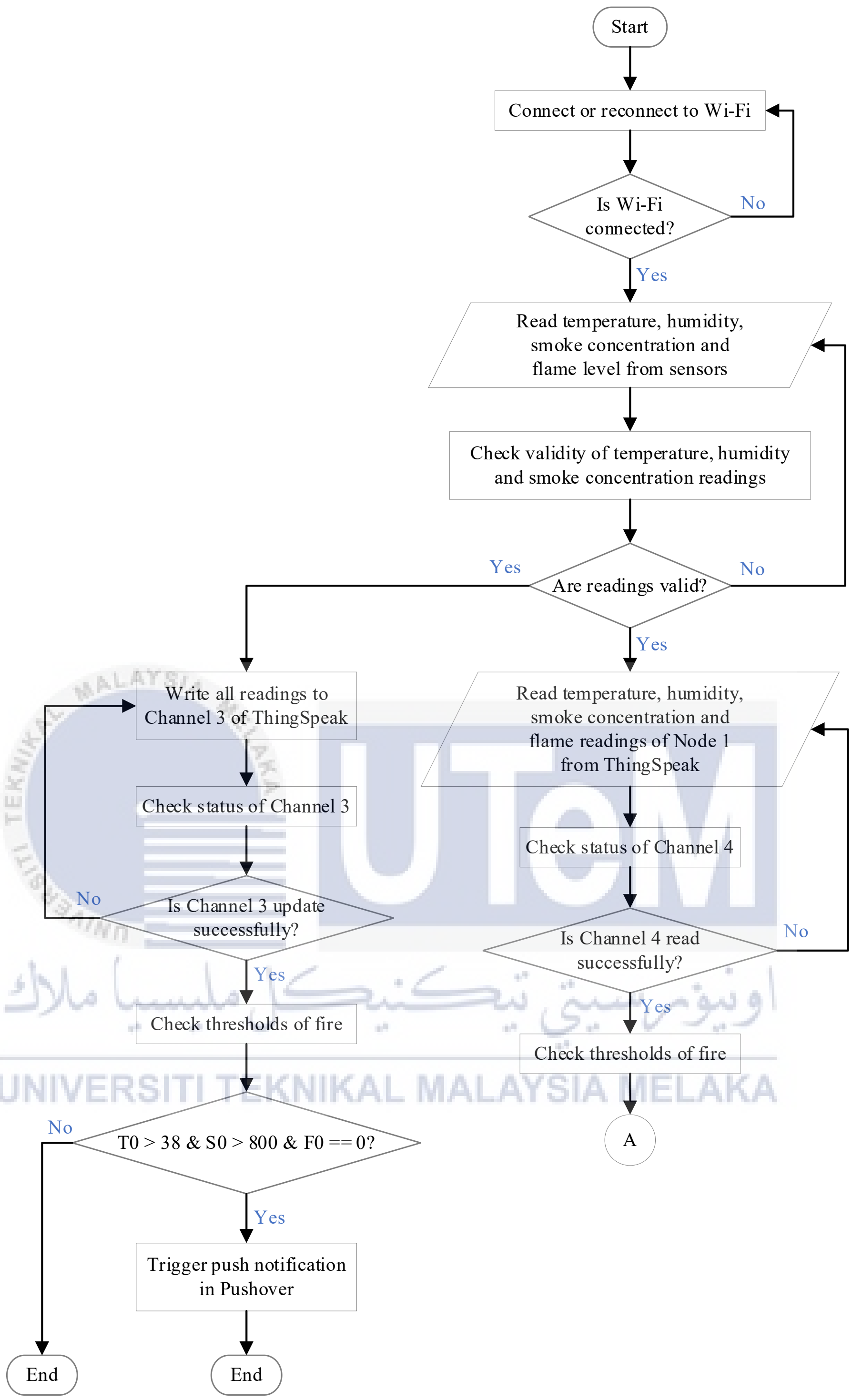


Figure 3.27: Flowchart of node 0 at outer side

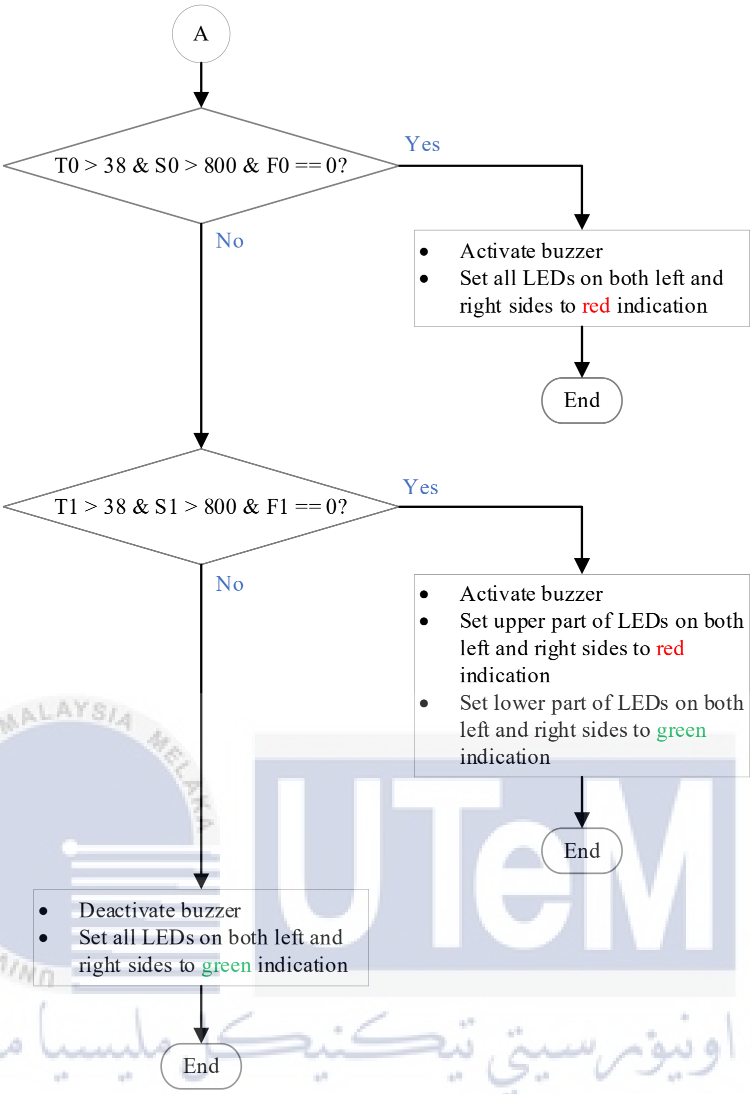


Figure 3.27: Flowchart of node 0 at outer side, continued

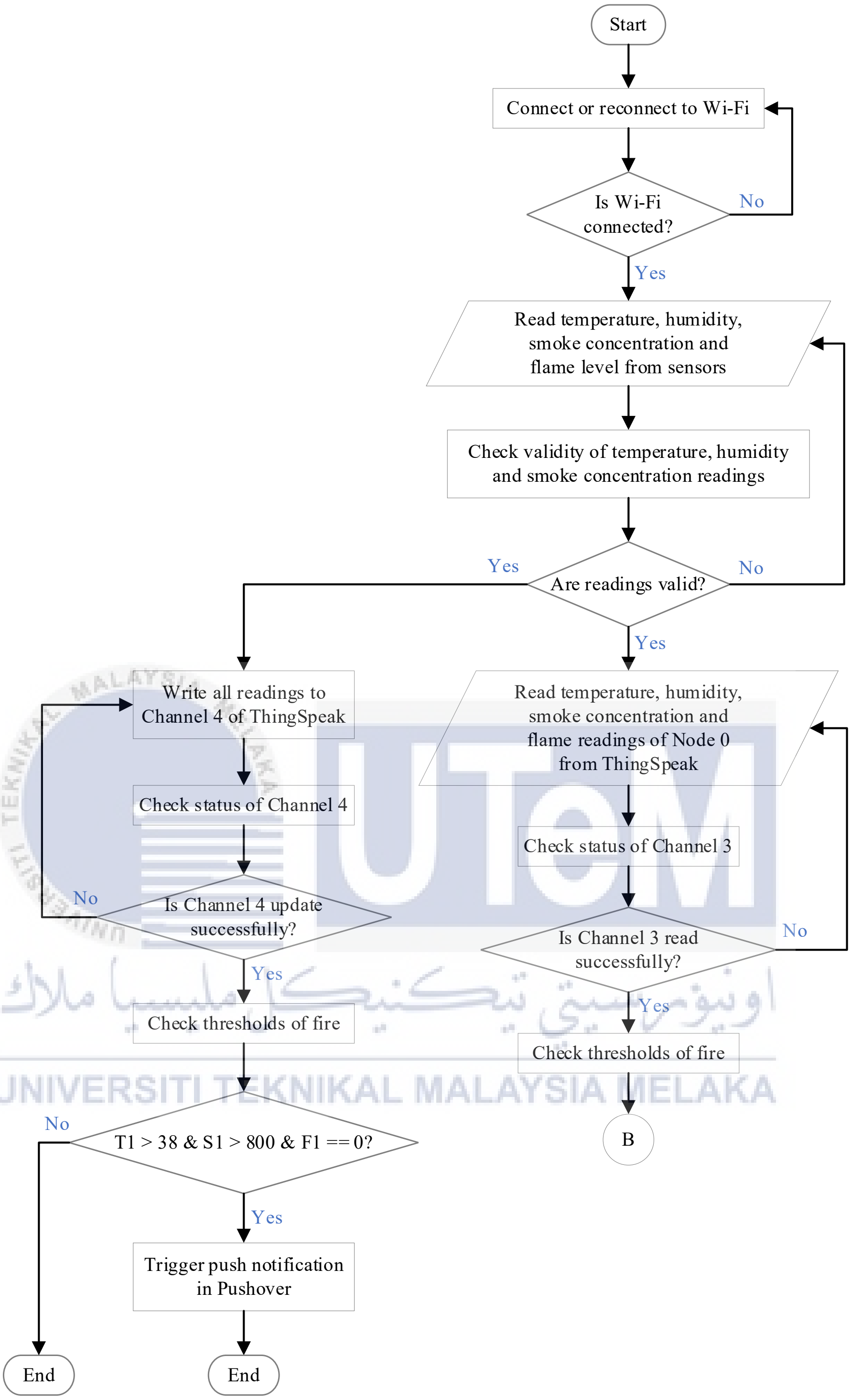


Figure 3.28: Flowchart of node 1 at outer side

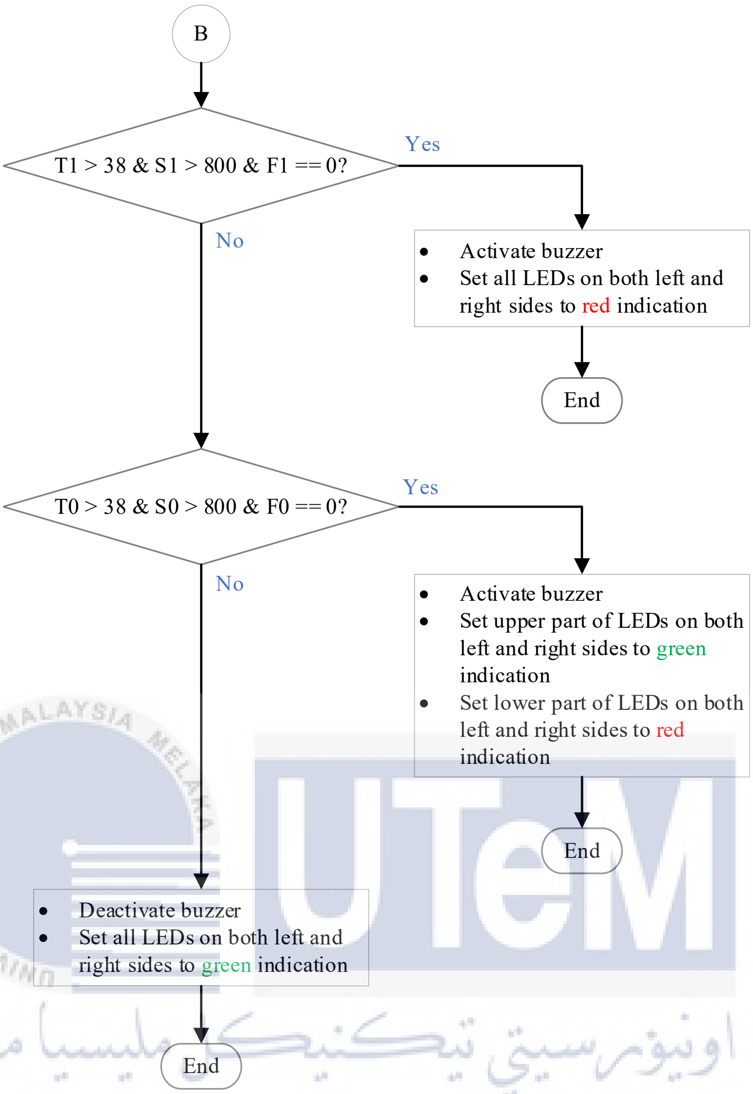


Figure 3.28: Flowchart of node 1 at outer side, continued

Based on the flowcharts in Figure 3.25, Figure 3.26, Figure 3.27 and Figure 3.28, a push notification is sent to alert the building occupants and the rescue teams through the Internet when the temperature is above 38 ºC, the smoke concentration is above 800 parts per million (ppm), and the flame level is equal to 0. Apart from the message notification, the alarm is activated, and the LEDs is flashed accordingly to the real-time fire condition to guide the building occupants in evacuation. Meanwhile, the rescue teams, such as firefighters, can efficiently utilise the red indication of the LEDs mounted on the emergency exit door to locate and put out the fire in the multi-story building.

According to the information of World Weather and Climate, the monthly average maximum temperature in the capital city of Malaysia, Kuala Lumpur, is around 33 ºC or 91.4 ºF, as illustrated in Figure 3.29 [29]. The conversion of temperature is presented in Equation 3.1. Based on Appendix F, the DHT11 temperature and humidity sensor used in this system has an accuracy of ±2 ºC. Therefore, the fire threshold of 38 ºC was chosen in case. However, the threshold should be adjusted depending on the condition of the environment.

$$ºC = \frac{ºF - 32}{1.8} \quad (3.1)$$

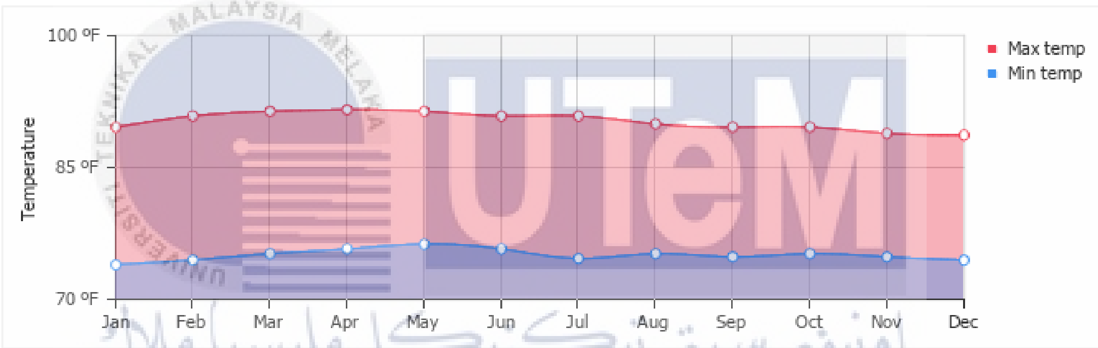


Figure 3.29: Average min and max temperatures (ºF) in Kuala Lumpur, Malaysia

According to the Brandforsk Project 702-041 by Tommy Hertzberg et al. (2005), the estimation of egress time from burning buildings is the major interest in risk evaluation. Engineering needs a design fire and the knowledge of fire gases produced. Carbon monoxide (CO) has been considered as the sole explanation for fire smoke intoxication. Nevertheless, other toxic substances might be present in the smoke. The American National Institute for Occupational Safety and Health (NIOSH) defines and lists the concentration levels for different substances as being Immediately Dangerous to Life and Health (IDLH) values, as shown in Table 3.6 [30]. Hence, the fire threshold of 800 ppm was selected for the smoke concentration. The lower threshold value was selected to allow more response time for the building occupants.

Table 3.6: IDLH values for different substances

Substance	IDLH Value (ppm)
Isocyanates	3
CO	1200
NO	100
HCN	50
HCl	50
NH3	300
HF	30

Figure 3.30 depicts the relationship between the analogue and digital output of the KY-026 flame sensor module. When a fire is detected, a HIGH (or logic 1) is given in the digital output pin; otherwise, logic 0 is given. However, a high numeric value is returned when there is no flame, and it is dropped to zero in the presence of fire. Thus, the fire threshold of 0 was chosen for the fire class. The potentiometer was turned clockwise to increase the sensitivity of the digital output to 1 m.

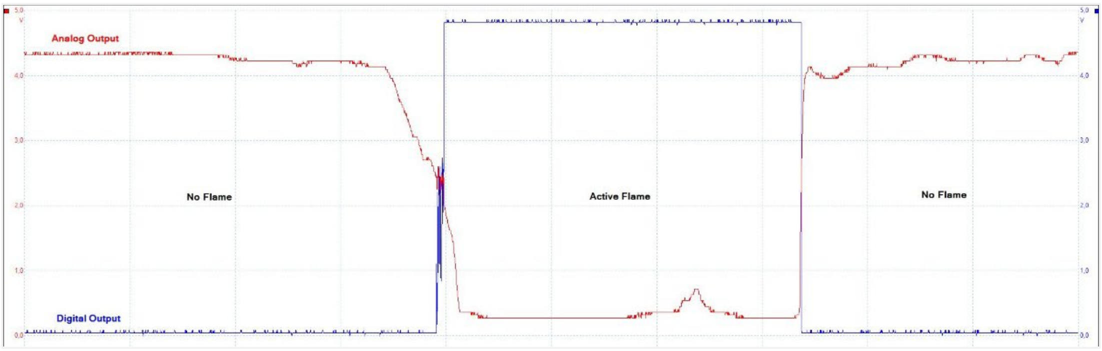


Figure 3.30: Relationship between analogue and digital output of KY-026 flame sensor

3.7 Planning of Project

Project planning is a fragment of project management. Planning is required to identify the desired goals, minimises risks, prevent missed deadlines and eventually deliver the proposed project and result. Table 3.7 shows the Gantt chart of the project, and the expected milestones are marked with "X" on it.

Table 3.7: Gantt chart of project

Project Activities	SEM 1															SEM BREAK				SEM 2															SPECIAL SEM			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Project Title Selection																																						
Literature Review																																						
Proposal Preparation & Submission				X																																		
Material Procurement																																						
Algorithm Development / Coding																						X																
Project Design & Development																								X														
Prototype Testing																																						
Result & Analysis																																X						
Report & Video Preparation																																						
Final Submission																																						X

3.8 Cost of Project

Based on Table 3.8, the total cost to construct and develop the project "Design of an Automated Illuminated Emergency Exit Door System (Auto IEED)" is RM 250.40. Although the cost of the project has exceeded the given budget, which is RM 200, it is still affordable. Most of the components or materials, such as DHT11 temperature and humidity sensors, piezo buzzers, 18650 Li-ion batteries, LM7805 ICs, electrolytic capacitors, battery holders, female header pins, heatsinks, jumper wires and UV boards, were requested from the component store of Faculty of Electronics and Computer Engineering (FKEKK). The software involved in the development of this project was free to download and use. In short, the cost to build the prototype is reasonable, and hereof the project was delivered successfully.

Table 3.8: Cost of project

No.	Component / Material	Quantity	Unit Price (RM)	Amount (RM)
1	NodeMCU ESP32	4	32.70	130.80
2	DHT11 Temperature and Humidity Sensor	4	-	-
3	MQ-2 Gas/Smoke Sensor	4	6.00	24.00
4	KY-026 Flame Sensor	4	4.50	18.00
5	Piezo Buzzer	4	-	-
6	SK6812 LEDs	8	9.70	77.60
7	18650 Li-Ion Battery	8	-	-
8	LM7805 IC	4	-	-
9	10 µF Electrolytic Capacitor	4	-	-
10	100 µF Electrolytic Capacitor	4	-	-
11	Battery Holder	4	-	-
12	Female Header Pin	4	-	-
13	Heatsink	4	-	-
14	Jumper Wire	24	-	-
15	UV Board	4	-	-
			Total	250.40

CHAPTER 4

RESULTS, ANALYSIS AND DISCUSSION

This chapter presents the results and findings obtained in the implementation of this project. It clearly sets up the expected and experimental results, and analyses the related sensor readings and luminosity of the system. It also discusses the environmental and sustainability features of this project.

4.1 Prototype of Auto IEED System

The hardware of an Auto IEED system is shown in Figure 4.1. It consisted of the four major elements: power supply unit, control and processing unit, alerting and indicating unit and detector system. As mentioned in Section 3.2, NodeMCU ESP32 was used as the control and processing unit in this system. The detector system was an integration of DHT11 temperature and humidity sensor, MQ-2 gas/smoke sensor and KY-026 flame sensor. Meanwhile, the alerting and indicating unit was an integration of piezo buzzer and LED strips. The jumper wires soldered on the UV board were used to connect the system to the SK6812 LEDs mounted on the emergency exit door.

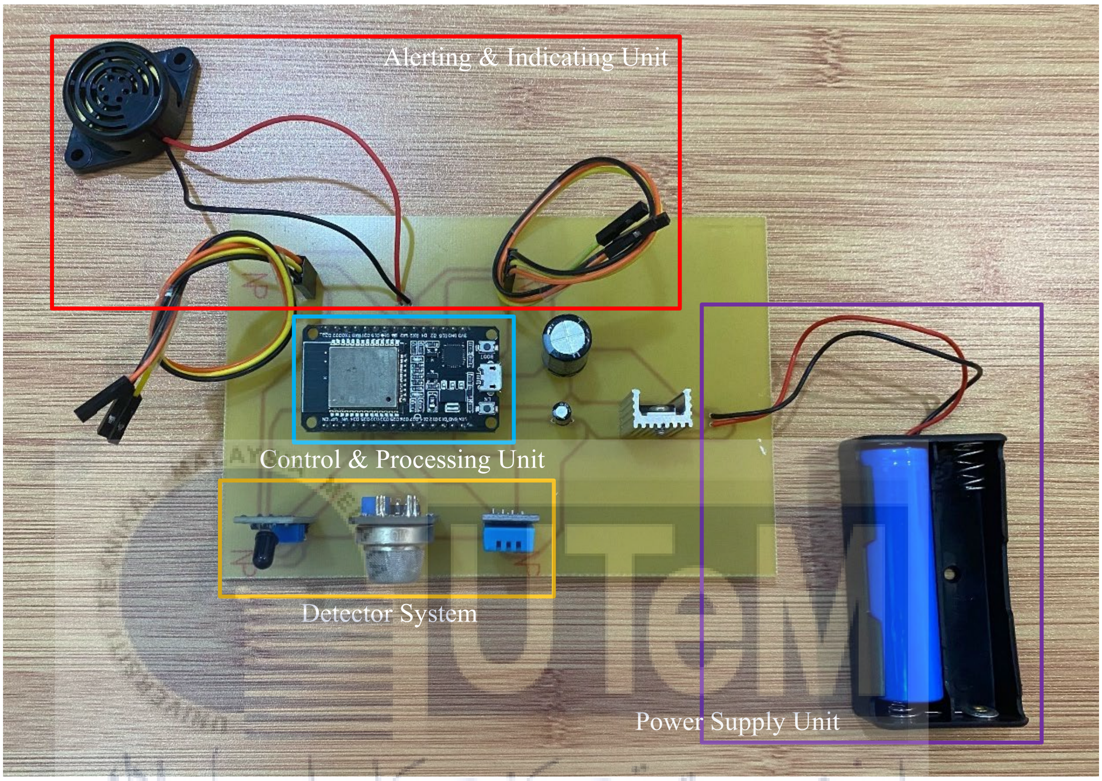


Figure 4.1: Hardware of Auto IEED system

4.2 Expected and Experimental Results of Prototype

As declared in Section 3.6, this project is designed to be implemented at the exit of an exit route in a multi-story building. Thus, the Auto IEED system is intended to be installed at both sides of an emergency exit door on each floor. The overview of the implementation concept of this project is illustrated in Figure 4.2. In this project, two floors were used for the execution. Consequently, there were be a total number of four sets of Auto IEED systems installed in the building. Assume that the area facing the staircase is the outer side, whereas the area facing the interior of the building is the inner side.

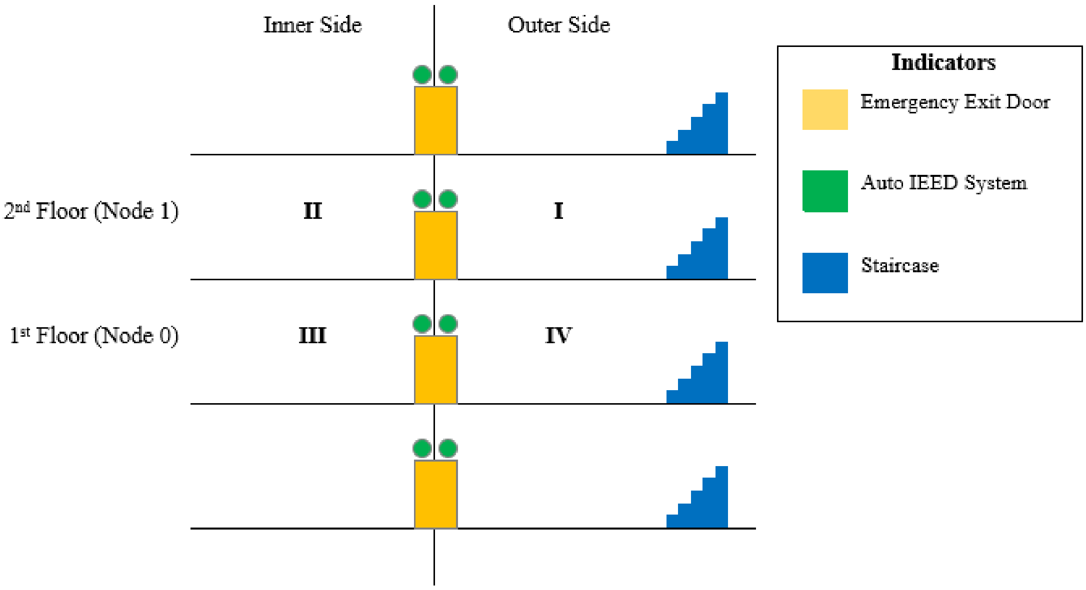


Figure 4.2: Overview of implementation concept of Auto IEED system

Consider Figure 4.2, the locations of fire caught in the building are divided into four quadrants. Let the Auto IEED system installed in Quadrant I be System A, in Quadrant II be System B, in Quadrant III be System C and in Quadrant IV be system D respectively. The installation of an Auto IEED system was such that its SK6812 LEDs were on the opposite side. For example, System A is installed on the outer side, but its LEDs are mounted on the inner side. The expected result of this project based on the fire locations in the building is tabulated in Table 4.1.

Table 4.1: Expected result of Auto IEED system

No.	Inputs				Outputs											
	Location of Fire				Indication of LEDs						Buzzer				Notification	
	I	II	III	IV	A		B	C	D		A	B	C	D	N0	N1
					U	L			U	L						
1	0	0	0	0							0	0	0	0	0	0
2	0	0	0	1							1	0	0	1	1	0
3	0	0	1	0							0	0	1	0	1	0
4	0	0	1	1							1	0	1	1	1	0
5	0	1	0	0							0	1	0	0	0	1
6	0	1	0	1							1	1	0	1	1	1
7	0	1	1	0							0	1	1	0	1	1
8	0	1	1	1							1	1	1	1	1	1

Table 4.1: Expected result of Auto IEED system, continued

9	1	0	0	0							1	0	0	1	0	1
10	1	0	0	1							1	0	0	1	1	1
11	1	0	1	0							1	0	1	1	1	1
12	1	0	1	1							1	0	1	1	1	1
13	1	1	0	0							1	1	0	1	0	1
14	1	1	0	1							1	1	0	1	1	1
15	1	1	1	0							1	1	1	1	1	1
16	1	1	1	1							1	1	1	1	1	1

Based on Table 4.1, logic 1 in the *Location of Fire* indicates that there is a presence of fire in the specific quadrant of the building, else there is no presence of fire. The SK6812 LED strips of Auto IEED systems at the outer side are divided into two parts: upper part (U) and lower part (L). Each part consists of 30 LEDs in a strip. A logic 1 in the *Buzzer* implies that the piezo buzzer of the respective system is activated, else the piezo buzzer is not activated. Moreover, logic 1 in the *Notification* infers that a push notification is sent to the registered mobile device via Pushover according to the presence of fire at the 1st floor (node 0 / N0) and the 2nd floor (node 1 / N1).

The experiment was conducted at daytime and night time for each possible fire condition in the building, as listed in Table 4.1. The experimental result obtained was identical to the expected result. Some of the important fire conditions in the building are presented and explained in the following subsections.

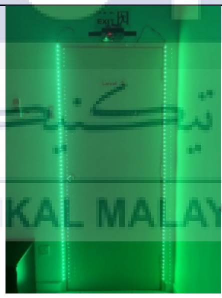
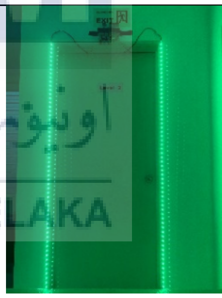
4.2.1 Condition 3: Fire at Quadrant III

In the experiment, a small fire was set up in Quadrant III of the building. The experimental result of the Auto IEED system is shown in Table 4.2 and Table 4.3. Figure 4.3 summarises the result at Condition 3.

Table 4.2: Experimental result of condition 3 at daytime

	Inner Side	Outer Side
Node 1		
Node 0		

Table 4.3: Experimental result of condition 3 at night time

	Inner Side	Outer Side
Node 1		
Node 0		

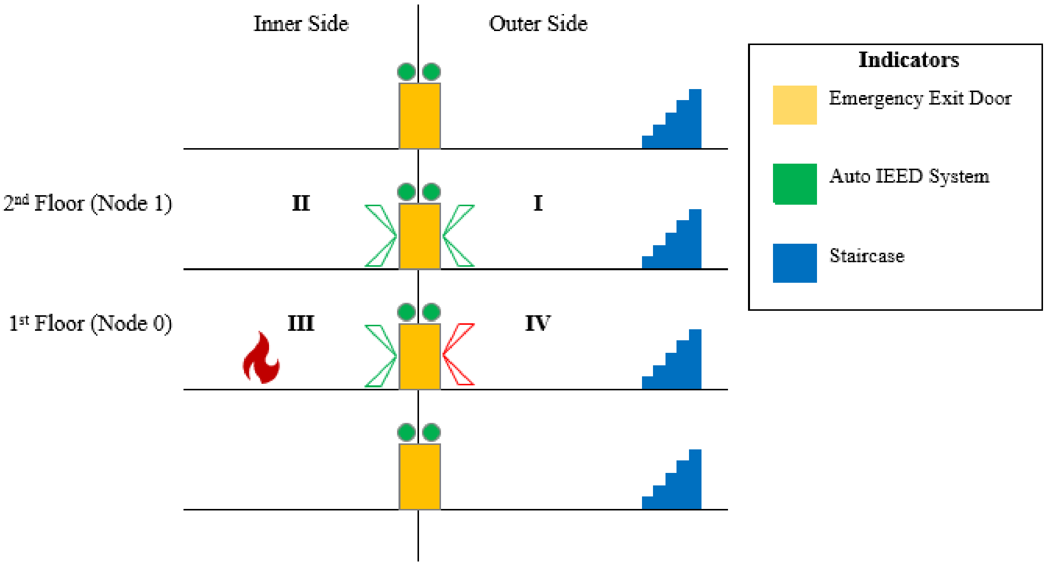


Figure 4.3: Summary of result at condition 3

Based on the result obtained, the LED indicator of System C appeared to be red, and its piezo buzzer was activated. At the same time, a push notification was sent to the registered mobile device, as depicted in Figure 4.4. In this case, the designed project implies that there is a fire on the first floor. It shows the occupants that the emergency exit door at Quadrant IV in the building is unsafe to enter during the evacuation process.

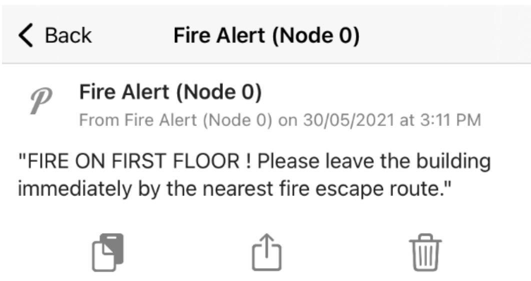


Figure 4.4: Push notification at condition 3

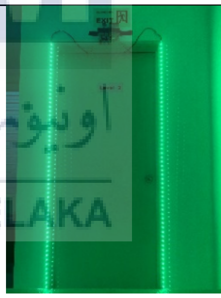
4.2.2 Condition 4: Fire at Quadrant III and IV

In the experiment, a small fire was set up on the 1st floor (Quadrant III and IV) of the building. The experimental result of the Auto IEED system is shown in Table 4.4 and Table 4.5. Figure 4.5 summarises the result at Condition 4.

Table 4.4: Experimental result of condition 4 at daytime

	Inner Side	Outer Side
Node 1		
Node 0		

Table 4.5: Experimental result of condition 4 at night time

	Inner Side	Outer Side
Node 1		
Node 0		

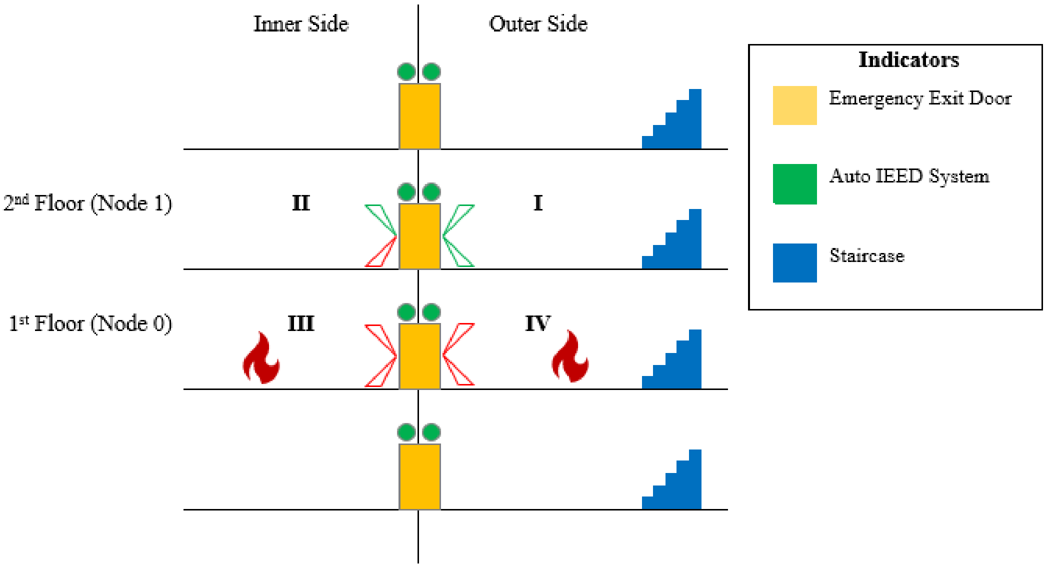


Figure 4.5: Summary of result at condition 4

Based on the result obtained, the LED indicators of both System C and System D appeared to be red, and the piezo buzzers were activated. Moreover, the lower part of the LED indicator of System A appeared to be red, and its piezo buzzer was activated. Meanwhile, a push notification was sent to the registered mobile device, as depicted in Figure 4.6. In this case, the designed project indicates that there is a fire on the first floor. It shows the occupants at Quadrant II that the lower floor is unsafe to go through during the evacuation process.

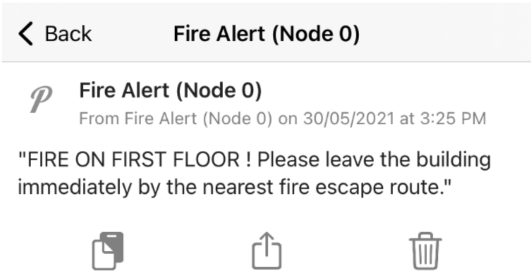


Figure 4.6: Push notification at condition 4

4.2.3 Condition 5: Fire at Quadrant II

In the experiment, a small fire was set up in Quadrant II of the building. The experimental result of the Auto IEED system is shown in Table 4.6 and Table 4.7. Figure 4.7 recaps the result at Condition 5.

Table 4.6: Experimental result of condition 5 at daytime

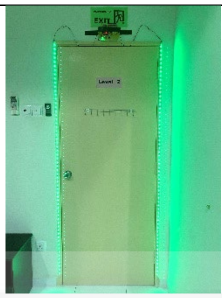
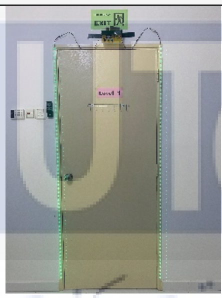
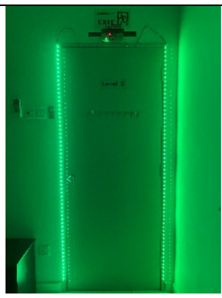
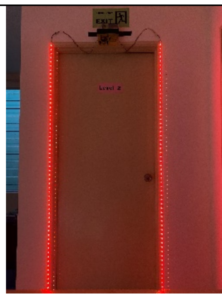
	Inner Side	Outer Side
Node 1		
Node 0		

Table 4.7: Experimental result of condition 5 at night time

	Inner Side	Outer Side
Node 1		
Node 0		

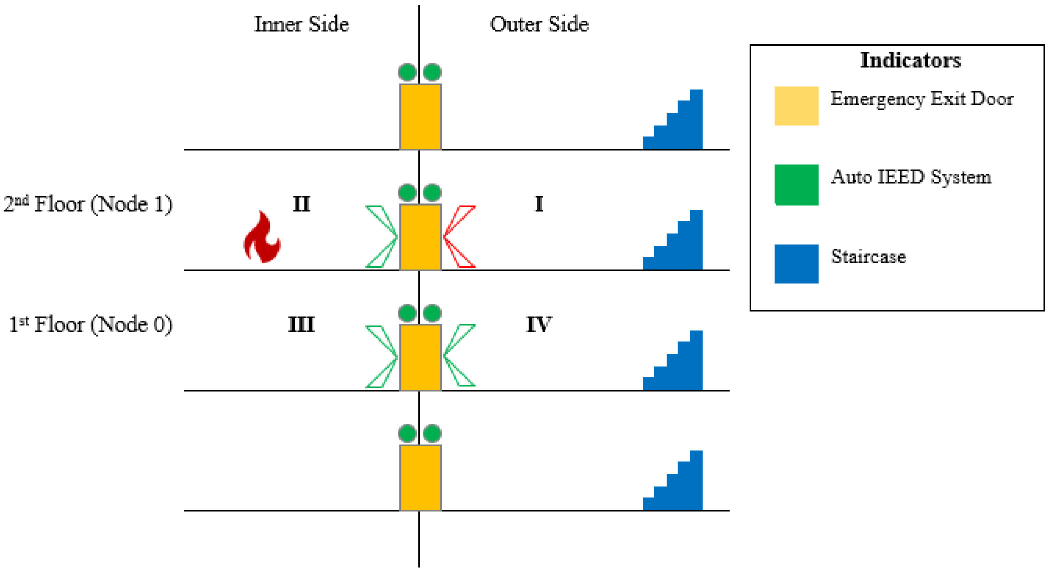


Figure 4.7: Summary of result at condition 5

Based on the result obtained, the LED indicator of System B appeared to be red, and its piezo buzzer was activated. At the same time, a push notification was sent to the registered mobile device, as depicted in Figure 4.8. In this case, the designed project implies that there is a fire on the second floor. It shows the occupants that the emergency exit door at Quadrant I in the building is unsafe to enter during the evacuation process.

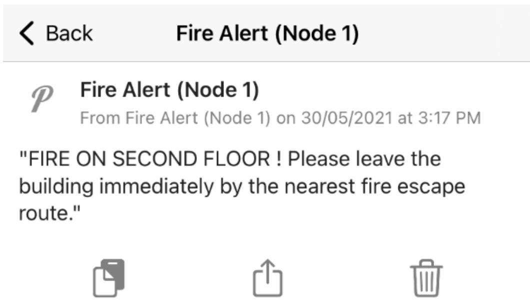


Figure 4.8: Push notification at condition 5

4.2.4 Condition 13: Fire at Quadrant I and II

In the experiment, a small fire was set up on the 2nd floor (Quadrant I and II) of the building. The experimental result of the Auto IEED system is shown in Table 4.8 and Table 4.9. Figure 4.9 recaps the result at Condition 13.

Table 4.8: Experimental result of condition 13 at daytime

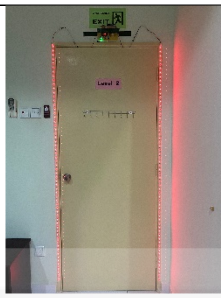
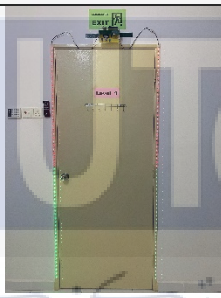
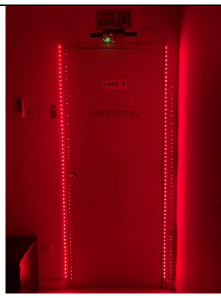
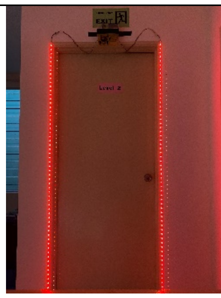
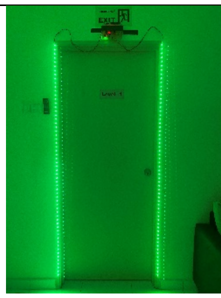
	Inner Side	Outer Side
Node 1		
Node 0		

Table 4.9: Experimental result of condition 13 at night time

	Inner Side	Outer Side
Node 1		
Node 0		

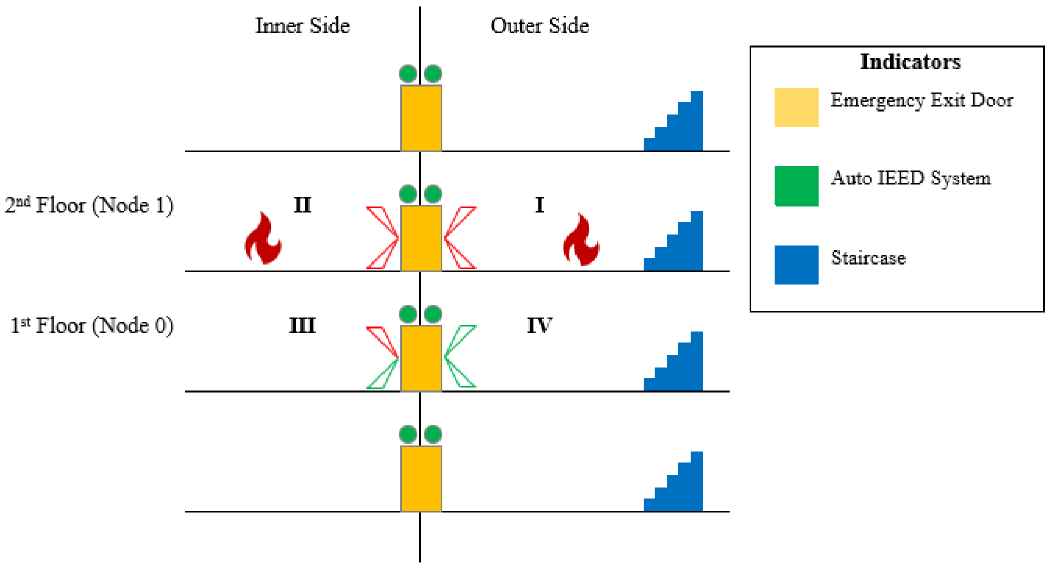


Figure 4.9: Summary of result at condition 13

Based on the result obtained, the LED indicators of both System A and System B appeared to be red, and the piezo buzzers were activated. Moreover, the upper part of the LED indicator of System D appeared to be red, and its piezo buzzer was activated. Meanwhile, a push notification was sent to the registered mobile device, as depicted in Figure 4.10. In this case, the designed project indicates that there is a fire on the second floor. It shows the occupants at Quadrant III that the upper floor is unsafe to go through during the evacuation process.

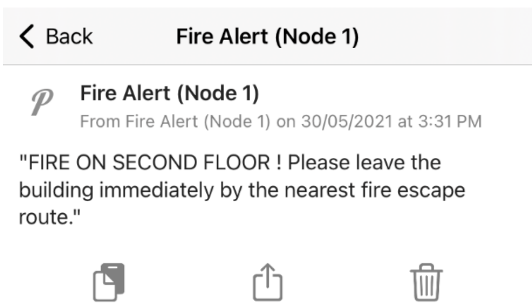


Figure 4.10: Push notification at condition 13

4.3 Analysis of Sensor Data in ThingSpeak

As stated in Section 3.4.4, the ThingSpeak IoT platform was used to retrieve, store and monitor data from the sensors over the Internet. In this project, two floors or nodes were used for the execution. Thus, four sets of Auto IEED systems: System A, System B, System C and System D, were installed in the building. The data obtained from each of the systems was visualised in graphical form in ThingSpeak. The following subsections present and discuss the charts with the latest 200 readings and a time-scaled of 10 for each system.

4.3.1 System A at Outer Side of 2nd Floor

Based on Figure 4.2, System A was installed in Quadrant I of the building. The latest 200 readings with a time-scaled of 10 from the sensors: DHT11 temperature and humidity sensor, MQ-2 smoke sensor and KY-026 flame sensor are illustrated in Figure 4.11, Figure 4.12, Figure 4.13 and Figure 4.14 respectively.

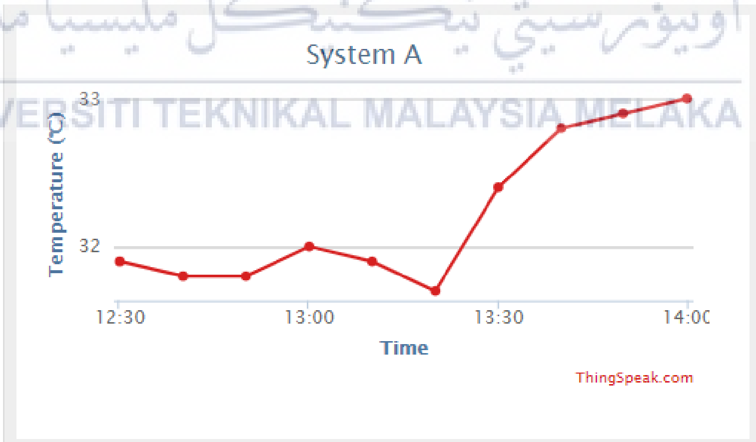


Figure 4.11: Temperature data of system A

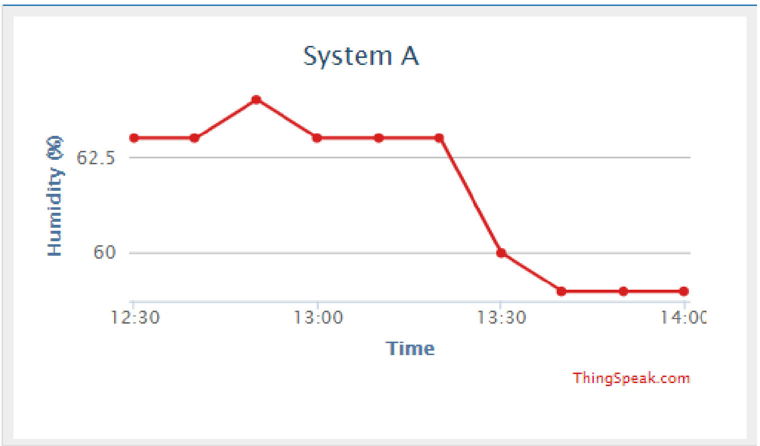


Figure 4.12: Humidity data of system A

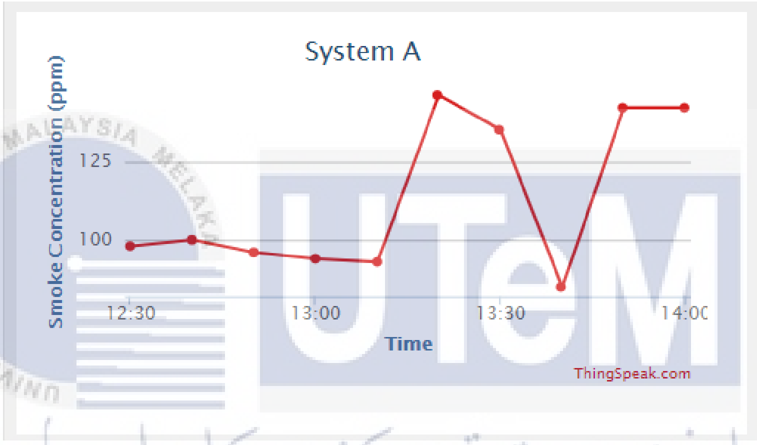


Figure 4.13: Smoke concentration data of system A

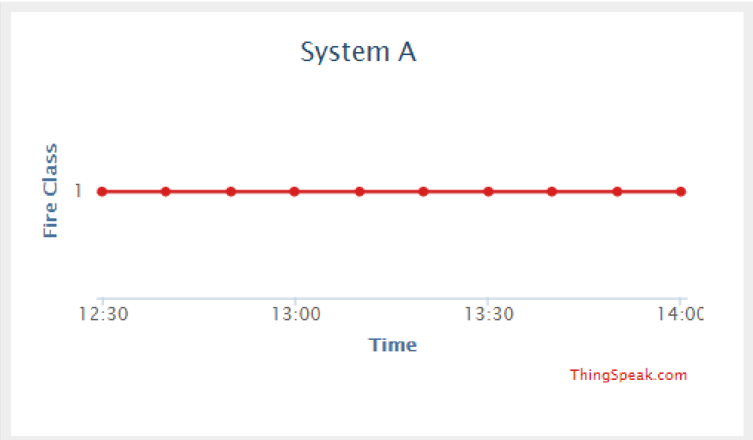


Figure 4.14: Fire class data of system A

Based on the result obtained, the temperature is in a range from 31.7 ºC to 33 ºC, humidity is in a range from 59 % to 64 %, smoke concentration is in a range from 85 ppm to 146 ppm, and the fire class is 1. The temperature is less than 38 ºC, the smoke concentration is less than 800 ppm, and the fire class is not equal to 0. The threshold of the fire set is not meet. Therefore, there was no presence of fire in Quadrant I of the building.

4.3.2 System B at Inner Side of 2nd Floor

According to Figure 4.2, System B was installed in Quadrant II of the building. The latest 200 readings with a time-scaled of 10 from the sensors: DHT11 temperature and humidity sensor, MQ-2 smoke sensor and KY-026 flame sensor are depicted in Figure 4.15, Figure 4.16, Figure 4.17 and Figure 4.18 correspondingly.

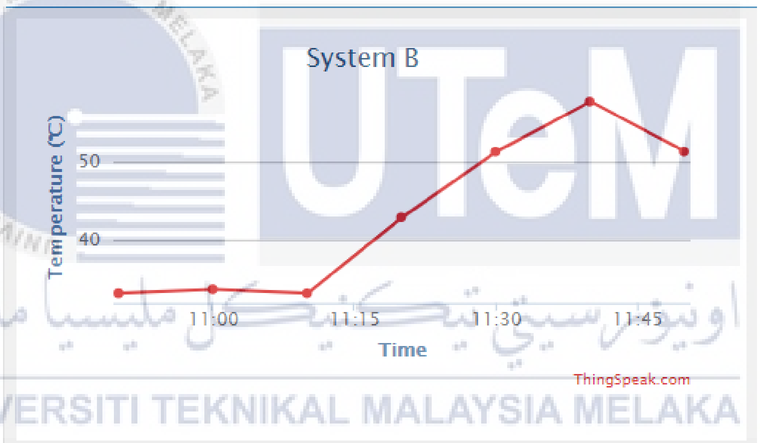


Figure 4.15: Temperature data of system B

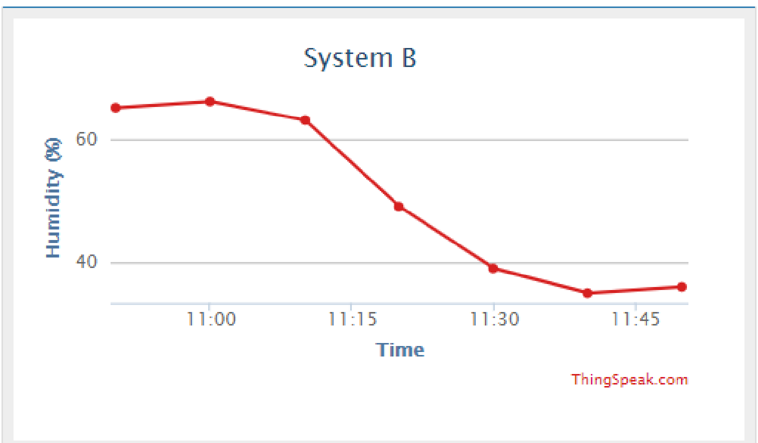


Figure 4.16: Humidity data of System B

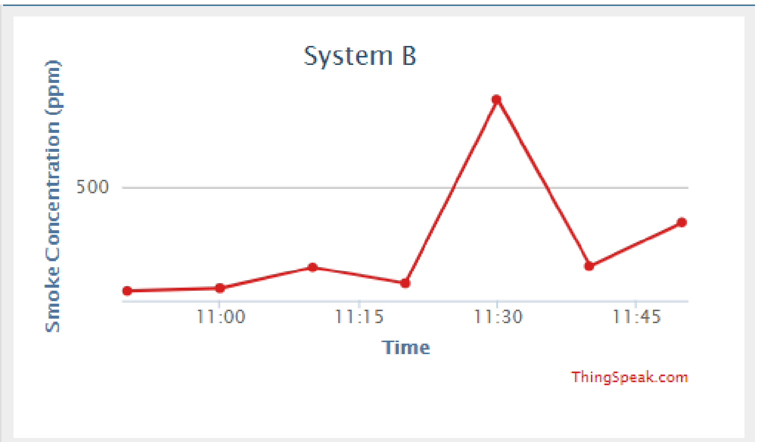


Figure 4.17: Smoke concentration data of system B

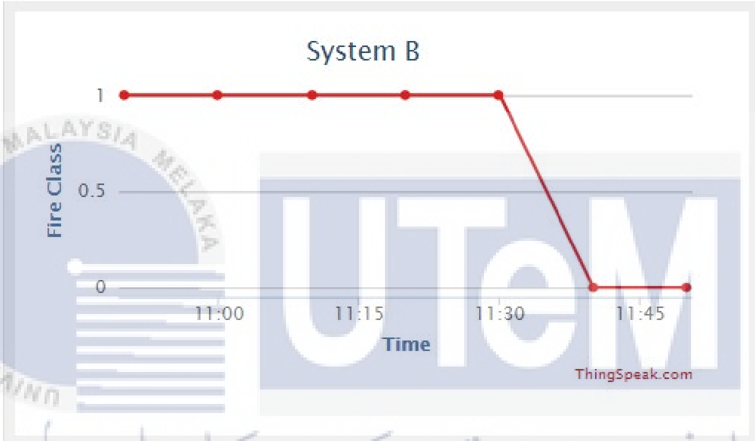


Figure 4.18: Fire class data of system B

Based on the result attained, the temperature is in a range from 33.2 ºC to 57.7 ºC, humidity is in a range from 35 % to 66 %, smoke concentration is in a range from 115 ppm to 825 ppm, and the fire class contains both 0 and 1. The temperature is greater than 38 ºC after point 3, the smoke concentration is greater than 800 ppm at point 5, and the fire class is equal to 0 after point 5. In this case, a fire was set up in Quadrant II of the building. Based on the complete information in ThingSpeak's database, System B was activated at 11:48:51 and 11:49:09, where the threshold of fire was met. At the moment, the temperatures were 54.6 ºC and 52.4 ºC, the smoke concentrations were 862 ppm and 922 ppm, and the fire class was both 0.

4.3.3 System C at Inner Side of 1st Floor

Based on Figure 4.2, System C was installed in Quadrant III of the building. The latest 200 readings with a time-scaled of 10 from the sensors: DHT11 temperature and humidity sensor, MQ-2 smoke sensor and KY-026 flame sensor are shown in Figure 4.19, Figure 4.20, Figure 4.21 and Figure 4.22 respectively.

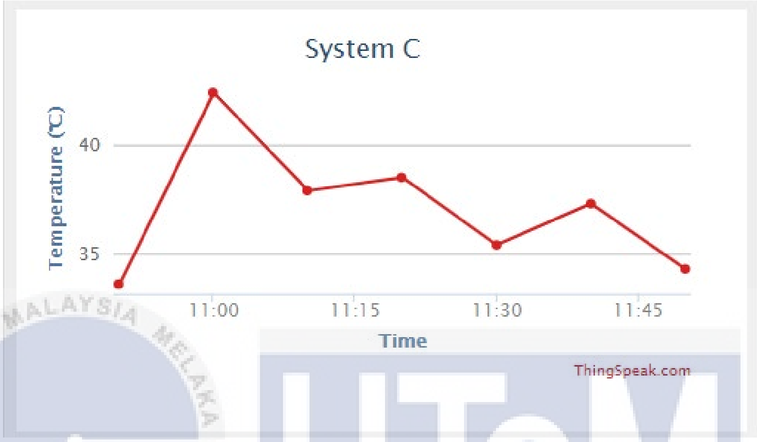


Figure 4.19: Temperature data of system C

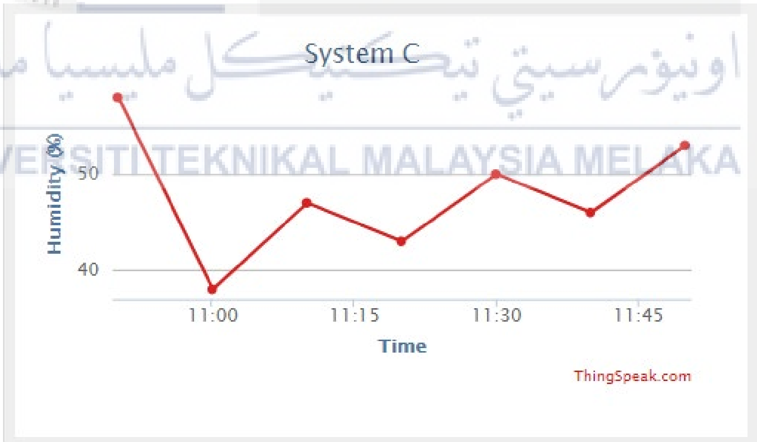


Figure 4.20: Humidity data of system C

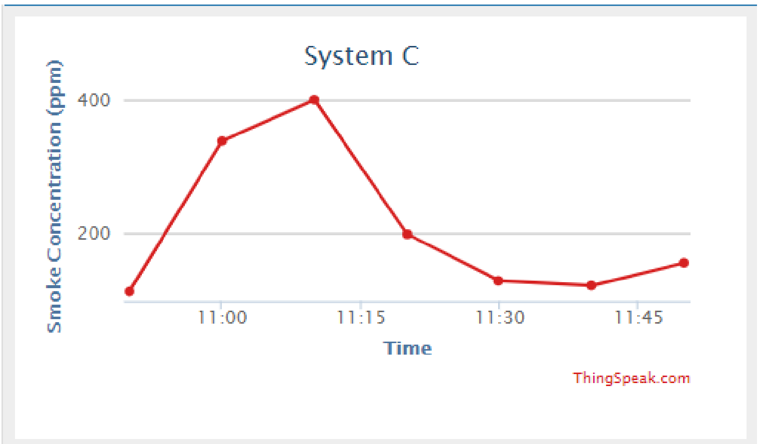


Figure 4.21: Smoke concentration data of system C

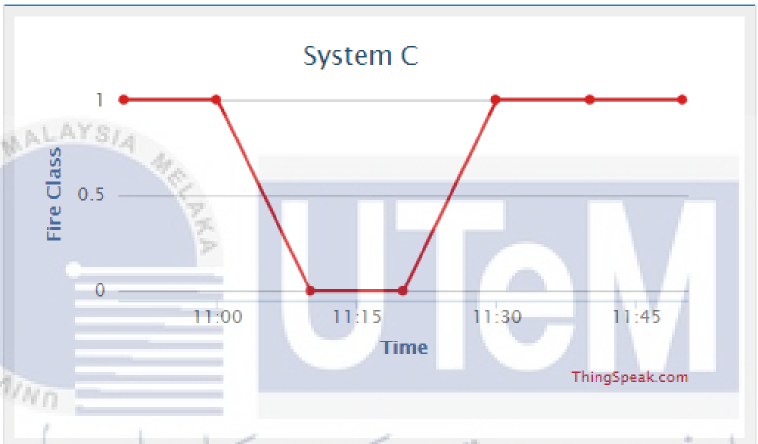


Figure 4.22: Fire class data of system C

Based on the result obtained, the temperature is in a range from 33.6 ºC to 42.4 ºC, humidity is in a range from 38 % to 58 %, smoke concentration is in a range from 112 ppm to 400 ppm, and the fire class contains both 0 and 1. The temperature is greater than 38 ºC at point 2 and point 4, the smoke concentration is less than 800 ppm, and the fire class is equal to 0 at point 3 and point 4. In this case, a fire was set up in Quadrant III of the building. Based on the detailed information in ThingSpeak's database, System C was activated at 11:16:15, where the threshold of fire was met. At the instant, the temperature was 42.6 ºC, the smoke concentration was 862 ppm, and the fire class was 0.

4.3.4 System D at Outer Side of 1st Floor

According to Figure 4.2, System D was installed in Quadrant IV of the building. The latest 200 readings with a time-scaled of 10 from the sensors: DHT11 temperature and humidity sensor, MQ-2 smoke sensor and KY-026 flame sensor are illustrated in Figure 4.23, Figure 4.24, Figure 4.25 and Figure 4.26 respectively.

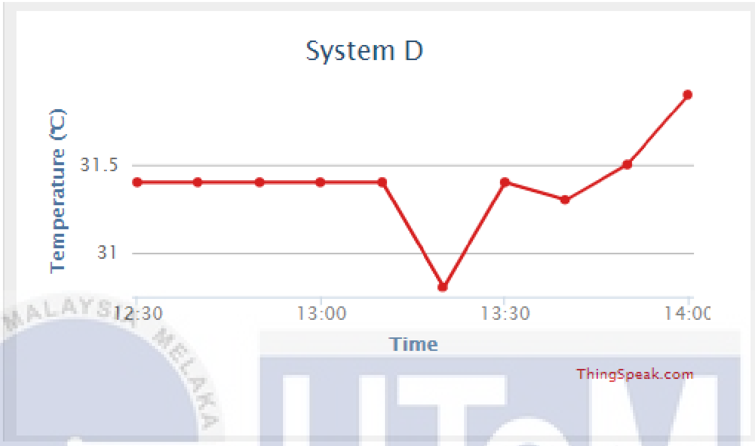


Figure 4.23: Temperature data of system D

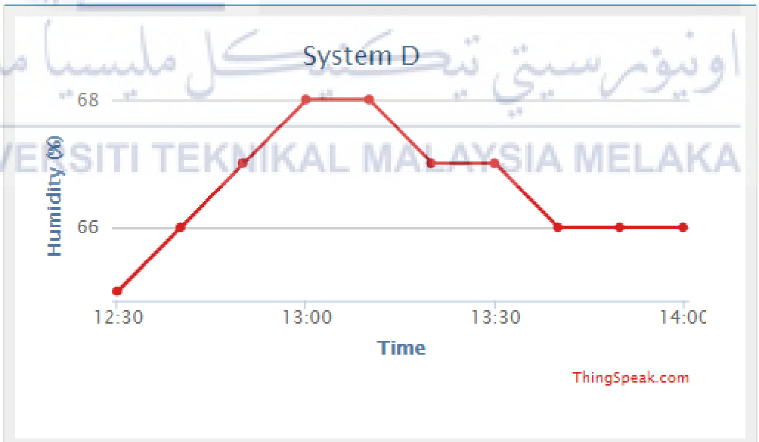


Figure 4.24: Humidity data of system D

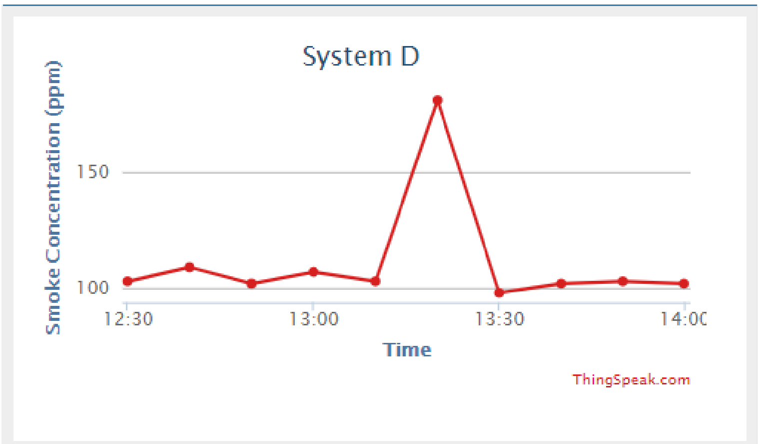


Figure 4.25: Smoke concentration data of system D

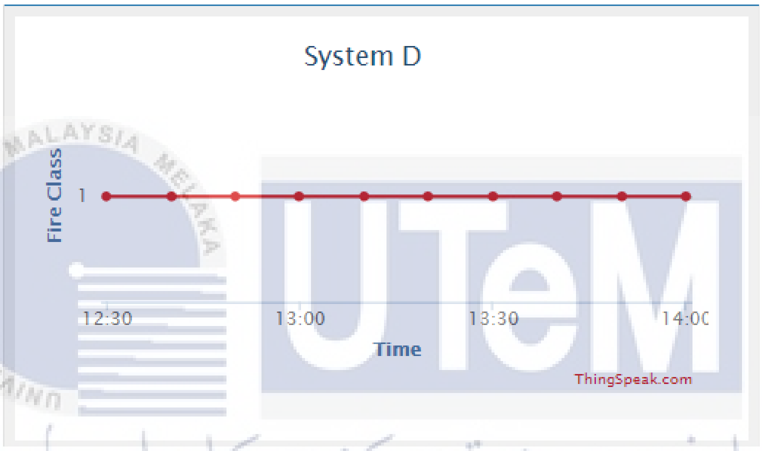


Figure 4.26: Fire class data of system D

Based on the result attained, the temperature is in a range from 30.8 ºC to 31.9 ºC, humidity is in a range from 65 % to 68 %, smoke concentration is in a range from 98 ppm to 181 ppm, and the fire class is 1. The temperature is less than 38 ºC, the smoke concentration is less than 800 ppm, and the fire class is not equal to 0. The threshold of the fire set is not meet. As a result, there was no presence of fire in Quadrant IV of the building.

4.4 Analysis of Luminous Intensity

As mentioned in Section 3.4.6, Lux Light Meter Pro was used to measure the luminosity of SK6812 LEDs in the surroundings of the project. The result is tabulated in Table 4.10 and Figure 4.27 for measurements at various distances.

Table 4.10: Luminosity measurement of Auto IEED system

Distance (m)	Luminosity (Lux)							
	Red Indication				Green Indication			
	1	2	3	Mean	1	2	3	Mean
0.5	83	82	82	82.3	88	87	88	87.7
1.0	59	60	58	59	65	63	61	63
1.5	21	19	19	19.7	24	24	23	23.7
2.0	5	5	4	4.7	7	6	8	7
2.5	1	1	3	1.7	3	2	2	2.3
3.0	1	1	1	1	1	1	1	1

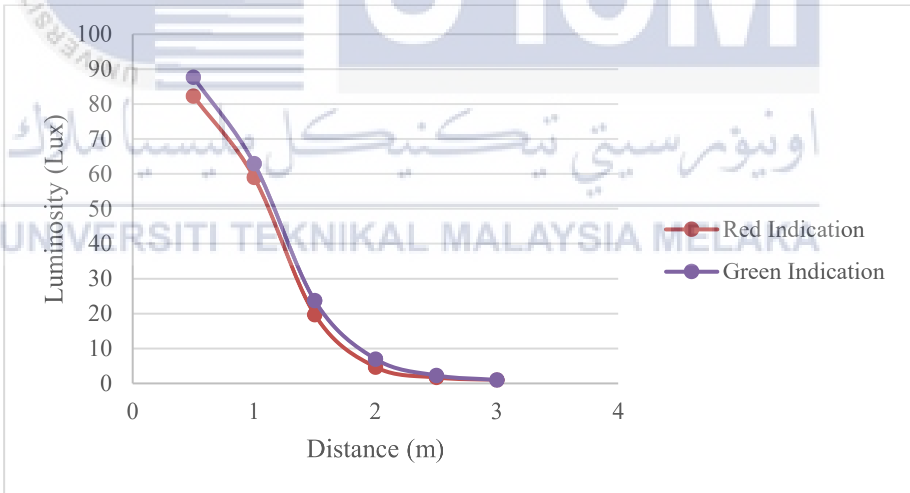


Figure 4.27: Luminosity of Auto IEED system

Based on the result obtained, the luminous intensity of both red and green indications decreases with distance. The luminous intensity of the green indication is slightly greater than that of the red indication. At a distance of 3.0 m, both colours of indication have an identical amount of luminosity, which is 1 lux.

4.5 Environment and Sustainability

The designed project which used LED technology is environmentally friendly. LEDs are 80 % more effective than conventional lightings, such as incandescent and fluorescent. Only 5 % of the energy in LEDs is lost as heat, while 95 % is turned into light. In comparison, fluorescent transforms 95 % of its energy into heat and only 5 % into light. LEDs also consume less energy than conventional lightings. Thus, the demand from power plants and the emission of greenhouse gas are reduced. Furthermore, LEDs have a longer life span results in lower emission of carbon. LEDs can last up to six times longer than conventional lightings, minimising the need for frequent replacements.

The designed project which used batteries as the main power supply is sustainable. The normal electrical supply within a building is interrupted and unavailable in a fire event. Auto IEED system is required for operation to assist the occupants in safe evacuation. Moreover, the designed project is scalable. The replacement of sensors in the detector system attributes the project to identify the presence of other hazards. For example, by substituting the fire detectors (DHT11 temperature and humidity sensor, MQ-2 smoke sensor, and KY-026 flame sensor) with flood detectors (ultrasonic sensor, etc.), the designed project is capable to act as a flood monitoring and alerting system. It guides the occupants to a higher and safer level in the multi-story building.

CHAPTER 5

CONCLUSION AND FUTURE WORKS

The main purpose of this project is to design and develop an Internet of Things (IoT) based emergency exit door system with the integration of multiple sensors to enhance the safety of building occupants in the early development of fire. The proposed system was designed to detect temperature, smoke and flame, and to initiate the visual and audible signals that alert and guide the occupants in the evacuation. It was able to solve the problems that arise from the conventional emergency exit door system. To minimise the false interpretation of fire, the electronic components that can represent a real-life system were selected and used in this project. Besides, the occupants can monitor the condition of the surroundings through the ThingSpeak platform. The source of the fire can be located easily with the help of the red indication of LEDs on the emergency exit doors. This information would be very helpful for rescue teams, such as firefighters, in the evacuation process. Experiments were carried out to prove the functionality and effectivity of the designed system. In short, with a reliable emergency exit door system in place, major property loss and more importantly injury to personnel can be alleviated.

5.1 Future Works

The use of LED strips in the project to assist the occupants in evacuation can be improved by using the arrow 7-segment LED displays to ease the interpretation of which floors or levels to go. Moreover, this designed project can be further advanced by the introduction of automation. Robots may be used on each floor to assist the occupants in evacuation when the presence of fire is detected in the building.

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APPENDICES

Appendix A: Code for System A at Outer Side of Node 1

```
// To set WiFi credentials
#include <WiFi.h>
/* D-09-05
const char ssid[] = "Maxis_468D84";
const char password[] = "14217504"; */
/* Sam's House
const char ssid[] = "SWEET HOME_2.4";
const char password[] = "ABCD062322460"; */
// Wendy's House
const char ssid[] = "IPHONE@unifi";
const char password[] = "68041707";
WiFiClient client;

// To set API keys from ThingSpeak
#include <ThingSpeak.h>
const long writeChannel = 1393916;
const long readChannel = 1392550;
const char writeAPI[] = "42DJ2RWG1I5L1V5P";
const char readAPI[] = "X8GT9IH65KML5M5G";

// To import necessary libraries
#include <DHT.h>
#include <FastLED.h>

// To define pin connections
#define DHTPIN 32
#define MQ2 35
#define KY026 34
#define Buzzer 2
```

```
#define LED_L 5
#define LED_R 15

// To select DHT sensor type
#define DHTTYPE DHT11
DHT dht(DHTPIN, DHTTYPE);

// To define number & array (name) of LEDs
#define LEDNUM 60
CRGB leds_L[LEDNUM];
CRGB leds_R[LEDNUM];

void setup()
{
  Serial.begin(115200);

  // To initialise ThingSpeak
  WiFi.mode(WIFI_STA);
  ThingSpeak.begin(client);

  // To initialise DHT11 sensor
  dht.begin();

  // To define digital data pin
  pinMode(KY026, INPUT);
  pinMode(Buzzer, OUTPUT);

  // To define type of LED strip & To assume GRB ordering
  FastLED.addLeds <WS2812, LED_L, GRB> (leds_L, LEDNUM);
  FastLED.addLeds <WS2812, LED_R, GRB> (leds_R, LEDNUM);
}

// To read from sensors & To write to ThingSpeak & To read from Thingspeak
void loop()
{
  // To connect or reconnect to WiFi
  if (WiFi.status() != WL_CONNECTED)
  {
    Serial.print("Connecting to SSID : ");
    Serial.println(ssid);
```

```
  Serial.println(".....");
  while (WiFi.status() != WL_CONNECTED)
  {
    WiFi.begin(ssid, password);
    delay(3000);
  }
  Serial.println("Connected.\n");
}

// To read temperature (in Celsius) & humidity takes about 250ms
float T1 = dht.readTemperature();
float H1 = dht.readHumidity();
// To read smoke concentration
int S1 = analogRead(MQ2);
// To identify flame
int F1 = digitalRead(KY026);
delay(1000);

// To check valid temperature & humidity readings
if (isnan(T1) || isnan(H1))
{
  Serial.println(F("Failed to read from DHT11 sensor!\n"));
  return;
}

// To check valid smoke concentration reading
if (isnan(S1))
{
  Serial.println(F("Failed to read from MQ2 smoke sensor!\n"));
  return;
}

// To print all readings of Node 1 on Serial Monitor
Serial.println("{ Readings from Node 1 }\n");
Serial.print(F("Temperature : "));
Serial.print(T1);
Serial.print(F(" °C     "));
Serial.print(F("Humidity : "));
Serial.print(H1);
Serial.print(" %     ");
Serial.print("Smoke : ");
```

```
  Serial.print(S1);
  Serial.print(" ppm     ");
  Serial.print("Fire Class : ");
  Serial.print(F1);
  Serial.print("\n");

  // To set fields with sensor values
  ThingSpeak.setField(1, T1);
  ThingSpeak.setField(2, H1);
  ThingSpeak.setField(3, S1);
  ThingSpeak.setField(4, F1);

  // To write to ThingSpeak channel
  int x = ThingSpeak.writeFields(writeChannel, writeAPI);
  delay(15000);

  if (x == 200)
  {
    Serial.println("Channel updated successfully.\n");
  }
  else
  {
    Serial.println("Unable to update channel. HTTP error code " +
String(x));
    Serial.print("\n");
  }

  // To read fields with sensor values
  float T0 = ThingSpeak.readFloatField(readChannel, 1, readAPI);
  float H0 = ThingSpeak.readFloatField(readChannel, 2, readAPI);
  int S0 = ThingSpeak.readIntField(readChannel, 3, readAPI);
  int F0 = ThingSpeak.readIntField(readChannel, 4, readAPI);

  // To read from ThingSpeak channel
  int y = ThingSpeak.getLastReadStatus();
  delay(5000);

  if (y == 200)
  {
    Serial.println("Channel read successfully.\n");
  }
```

```
else
{
  Serial.println("Unable to read channel. HTTP error code " +
String(y));
  Serial.print("\n");
}

// To print all readings of Node 0 on Serial Monitor
Serial.println("{ Readings from Node 0 }\n");
Serial.print(F("Temperature : "));
Serial.print(T0);
Serial.print(F(" °C     "));
Serial.print(F("Humidity : "));
Serial.print(H0);
Serial.print(" %     ");
Serial.print("Smoke : ");
Serial.print(S0);
Serial.print(" ppm     ");
Serial.print("Fire Class : ");
Serial.print(F0);
Serial.print("\n");

// To set threshold values of fire
if (T1>38 && S1>800 && F1==0)
{
  Serial.println("* FIRE ON 2ND FLOOR !!! *\n");
  digitalWrite(Buzzer, HIGH);

  // j loop controls brightness & i loop defines LEDs section
  for (int j=0; j<255; j++)
  {
    for (int i=0; i<LEDNUM; i++)
    {
      leds_L[i]=CRGB(j, 0, 0);
      leds_R[i]=CRGB(j, 0, 0);
    }
    FastLED.show();
  }
}
else if (T0>38 && S0>800 || F0==0)
{
```

```
    Serial.println("* FIRE ON 1ST FLOOR !!! *\n");
    digitalWrite(Buzzer, HIGH);

    for (int j=0; j<255; j++)
    {
      for (int i=0; i<30; i++)
      {
        leds_L[i]=CRGB(0, j, 0);
        leds_R[i]=CRGB(0, j, 0);
      }
      for (int i=30; i<LEDNUM; i++)
      {
        leds_L[i]=CRGB(j, 0, 0);
        leds_R[i]=CRGB(j, 0, 0);
      }
      FastLED.show();
    }
  }
  else
  {
    Serial.println("* NO FIRE *\n");
    digitalWrite(Buzzer, LOW);

    for (int j=0; j<255; j++)
    {
      for (int i=0; i<LEDNUM; i++)
      {
        leds_L[i]=CRGB(0, j, 0);
        leds_R[i]=CRGB(0, j, 0);
      }
      FastLED.show();
    }
  }
}
```

Appendix B: Code for System B at Inner Side of Node 1

```
// To set WiFi credentials
#include <WiFi.h>
/* D-09-05
const char ssid[] = "Maxis_468D84";
const char password[] = "14217504"; */
/* Sam's House
const char ssid[] = "SWEET HOME_2.4";
const char password[] = "ABCD062322460"; */
// Wendy's House
const char ssid[] = "IPHONE@unifi";
const char password[] = "68041707";
WiFiClient client;

// To set API keys from ThingSpeak
#include <ThingSpeak.h>
const long channel = 1392549;
const char writeAPI[] = "F1VTM31UKS9UTMUR";

// To import necessary libraries
#include <DHT.h>
#include <FastLED.h>

// To define pin connections
#define DHTPIN 32
#define MQ2 35
#define KY026 34
#define Buzzer 2
#define LED_L 5
#define LED_R 15

// To select DHT sensor type
#define DHTTYPE DHT11
DHT dht(DHTPIN, DHTTYPE);

// To define number & array (name) of LEDs
#define LEDNUM 60
CRGB leds_L[LEDNUM];
CRGB leds_R[LEDNUM];
```

```
void setup()
{
  Serial.begin(115200);

  // To initialise ThingSpeak
  WiFi.mode(WIFI_STA);
  ThingSpeak.begin(client);

  // To initialise DHT11 sensor
  dht.begin();

  // To define digital data pin
  pinMode(KY026, INPUT);
  pinMode(Buzzer, OUTPUT);

  // To define type of LED strip & To assume GRB ordering
  FastLED.addLeds <WS2812, LED_L, GRB> (leds_L, LEDNUM);
  FastLED.addLeds <WS2812, LED_R, GRB> (leds_R, LEDNUM);
}

// To read from sensors & To write to ThingSpeak
void loop()
{
  // To connect or reconnect to WiFi
  if (WiFi.status() != WL_CONNECTED)
  {
    Serial.print("Connecting to SSID : ");
    Serial.println(ssid);
    Serial.println(".....");
    while (WiFi.status() != WL_CONNECTED)
    {
      WiFi.begin(ssid, password);
      delay(3000);
    }
    Serial.println("Connected.\n");
  }

  // To read temperature (in Celsius) & humidity takes about 250ms
  float T = dht.readTemperature();
  float H = dht.readHumidity();
```

```
// To read smoke concentration
int S = analogRead(MQ2);
// To identify flame
int F = digitalRead(KY026);
delay(1000);

// To check valid temperature & humidity readings
if (isnan(T) || isnan(H))
{
  Serial.println(F("Failed to read from DHT11 sensor!\n"));
  return;
}

// To check valid smoke concentration reading
if (isnan(S))
{
  Serial.println(F("Failed to read from MQ2 smoke sensor!\n"));
  return;
}

// To print all readings of Node 1 on Serial Monitor
Serial.print(F("Temperature : "));
Serial.print(T);
Serial.print(F(" °C      "));
Serial.print(F("Humidity : "));
Serial.print(H);
Serial.print(" %     ");
Serial.print("Smoke : ");
Serial.print(S);
Serial.print(" ppm     ");
Serial.print("Fire Class : ");
Serial.print(F);
Serial.print("\n");

// To set threshold values of fire
if (T>38 && S>800 && F==0)
{
  Serial.println("* FIRE ON 2ND FLOOR !!! *\n");
  digitalWrite(Buzzer, HIGH);

  // j loop controls brightness & i loop defines LEDs section
```

```
  for (int j=0; j<255; j++)
  {
    for (int i=0; i<LEDNUM; i++)
    {
      leds_L[i]=CRGB(j, 0, 0);
      leds_R[i]=CRGB(j, 0, 0);
    }
    FastLED.show();
  }
}
else
{
  Serial.println("* NO FIRE *\n");
  digitalWrite(Buzzer, LOW);

  for (int j=0; j<255; j++)
  {
    for (int i=0; i<LEDNUM; i++)
    {
      leds_L[i]=CRGB(0, j, 0);
      leds_R[i]=CRGB(0, j, 0);
    }
    FastLED.show();
  }
}
```



```
// To set fields with sensor values
ThingSpeak.setField(1, T);
ThingSpeak.setField(2, H);
ThingSpeak.setField(3, S);
ThingSpeak.setField(4, F);

// To write to ThingSpeak channel
int x = ThingSpeak.writeFields(channel, writeAPI);
delay(15000);

if (x == 200)
{
  Serial.println("Channel updated successfully.\n");
}
else
```

```
  {
    Serial.println("Unable to update channel. HTTP error code " +
String(x));
    Serial.print("\n");
  }
}
```

Appendix C: Code for System C at Inner Side of Node 0

```
// To set WiFi credentials
#include <WiFi.h>
/* D-09-05
const char ssid[] = "Maxis_468D84";
const char password[] = "14217504"; */
/* Sam's House
const char ssid[] = "SWEET HOME_2.4";
const char password[] = "ABCD062322460"; */
// Wendy's House
const char ssid[] = "IPHONE@unifi";
const char password[] = "68041707";
WiFiClient client;

// To set API keys from ThingSpeak
#include <ThingSpeak.h>
const long channel = 1391658;
const char writeAPI[] = "U46RM8AD89S38XC8";

// To import necessary libraries
#include <DHT.h>
#include <FastLED.h>

// To define pin connections
#define DHTPIN 32
#define MQ2 35
#define KY026 34
#define Buzzer 2
#define LED_L 5
#define LED_R 15

// To select DHT sensor type
#define DHTTYPE DHT11
DHT dht(DHTPIN, DHTTYPE);

// To define number & array (name) of LEDs
#define LEDNUM 60
CRGB leds_L[LEDNUM];
CRGB leds_R[LEDNUM];
```

```
void setup()
{
  Serial.begin(115200);

  // To initialise ThingSpeak
  WiFi.mode(WIFI_STA);
  ThingSpeak.begin(client);

  // To initialise DHT11 sensor
  dht.begin();

  // To define digital data pin
  pinMode(KY026, INPUT);
  pinMode(Buzzer, OUTPUT);

  // To define type of LED strip & To assume GRB ordering
  FastLED.addLeds <WS2812, LED_L, GRB> (leds_L, LEDNUM);
  FastLED.addLeds <WS2812, LED_R, GRB> (leds_R, LEDNUM);
}

// To read from sensors & To write to ThingSpeak
void loop()
{
  // To connect or reconnect to WiFi
  if (WiFi.status() != WL_CONNECTED)
  {
    Serial.print("Connecting to SSID : ");
    Serial.println(ssid);
    Serial.println(".....");
    while (WiFi.status() != WL_CONNECTED)
    {
      WiFi.begin(ssid, password);
      delay(3000);
    }
    Serial.println("Connected.\n");
  }

  // To read temperature (in Celsius) & humidity takes about 250ms
  float T = dht.readTemperature();
  float H = dht.readHumidity();
```

```
// To read smoke concentration
int S = analogRead(MQ2);
// To identify flame
int F = digitalRead(KY026);
delay(1000);

// To check valid temperature & humidity readings
if (isnan(T) || isnan(H))
{
  Serial.println(F("Failed to read from DHT11 sensor!\n"));
  return;
}

// To check valid smoke concentration reading
if (isnan(S))
{
  Serial.println(F("Failed to read from MQ2 smoke sensor!\n"));
  return;
}

// To print all readings of Node 0 on Serial Monitor
Serial.print(F("Temperature : "));
Serial.print(T);
Serial.print(F(" °C      "));
Serial.print(F("Humidity : "));
Serial.print(H);
Serial.print(" %      ");
Serial.print("Smoke : ");
Serial.print(S);
Serial.print(" ppm      ");
Serial.print("Fire Class : ");
Serial.print(F);
Serial.print("\n");

// To set threshold values of fire
if (T>38 && S>800 && F==0)
{
  Serial.println("* FIRE ON 1ST FLOOR !!! *\n");
  digitalWrite(Buzzer, HIGH);

  // j loop controls brightness & i loop defines LEDs section
```

```
  for (int j=0; j<255; j++)
  {
    for (int i=0; i<LEDNUM; i++)
    {
      leds_L[i]=CRGB(j, 0, 0);
      leds_R[i]=CRGB(j, 0, 0);
    }
    FastLED.show();
  }
}
else
{
  Serial.println("* NO FIRE *\n");
  digitalWrite(Buzzer, LOW);

  for (int j=0; j<255; j++)
  {
    for (int i=0; i<LEDNUM; i++)
    {
      leds_L[i]=CRGB(0, j, 0);
      leds_R[i]=CRGB(0, j, 0);
    }
    FastLED.show();
  }
}
```



```
// To set fields with sensor values
ThingSpeak.setField(1, T);
ThingSpeak.setField(2, H);
ThingSpeak.setField(3, S);
ThingSpeak.setField(4, F);

// To write to ThingSpeak channel
int x = ThingSpeak.writeFields(channel, writeAPI);
delay(15000);

if (x == 200)
{
  Serial.println("Channel updated successfully.\n");
}
else
```

```
  {
    Serial.println("Unable to update channel. HTTP error code " +
String(x));
    Serial.print("\n");
  }
}
```

Appendix D: Code for System D at Outer Side of Node 0

```
// To set WiFi credentials
#include <WiFi.h>
/* D-09-05
const char ssid[] = "Maxis_468D84";
const char password[] = "14217504"; */
/* Sam's House
const char ssid[] = "SWEET HOME_2.4";
const char password[] = "ABCD062322460"; */
// Wendy's House
const char ssid[] = "IPHONE@unifi";
const char password[] = "68041707";
WiFiClient client;

// To set API keys from ThingSpeak
#include <ThingSpeak.h>
const long writeChannel = 1392550;
const long readChannel = 1393916;
const char writeAPI[] = "7A37SNOB3C1MCYDM";
const char readAPI[] = "GNLPFRFPO234HCMM";

// To import necessary libraries
#include <DHT.h>
#include <FastLED.h>

// To define pin connections
#define DHTPIN 32
#define MQ2 35
#define KY026 34
#define Buzzer 2
#define LED_L 5
#define LED_R 15

// To select DHT sensor type
#define DHTTYPE DHT11
DHT dht(DHTPIN, DHTTYPE);

// To define number & array (name) of LEDs
#define LEDNUM 60
```

```
CRGB leds_L[LEDNUM];
CRGB leds_R[LEDNUM];

void setup()
{
  Serial.begin(115200);

  // To initialise ThingSpeak
  WiFi.mode(WIFI_STA);
  ThingSpeak.begin(client);

  // To initialise DHT11 sensor
  dht.begin();

  // To define digital data pin
  pinMode(KY026, INPUT);
  pinMode(Buzzer, OUTPUT);

  // To define type of LED strip & To assume GRB ordering
  FastLED.addLeds <WS2812, LED_L, GRB> (leds_L, LEDNUM);
  FastLED.addLeds <WS2812, LED_R, GRB> (leds_R, LEDNUM);
}

// To read from sensors & To write to ThingSpeak & To read from
Thingspeak
void loop()
{
  // To connect or reconnect to WiFi
  if (WiFi.status() != WL_CONNECTED)
  {
    Serial.print("Connecting to SSID : ");
    Serial.println(ssid);
    Serial.println(".....");
    while (WiFi.status() != WL_CONNECTED)
    {
      WiFi.begin(ssid, password);
      delay(3000);
    }
    Serial.println("Connected.\n");
  }
```

```
// To read temperature (in Celsius) & humidity takes about 250ms
float T0 = dht.readTemperature();
float H0 = dht.readHumidity();
// To read smoke concentration
int S0 = analogRead(MQ2);
// To identify flame
int F0 = digitalRead(KY026);
delay(1000);

// To check valid temperature & humidity readings
if (isnan(T0) || isnan(H0))
{
  Serial.println(F("Failed to read from DHT11 sensor!\n"));
  return;
}

// To check valid smoke concentration reading
if (isnan(S0))
{
  Serial.println(F("Failed to read from MQ2 smoke sensor!\n"));
  return;
}

// To print all readings of Node 0 on Serial Monitor
Serial.println("{ Readings from Node 0 }\n");
Serial.print(F("Temperature : "));
Serial.print(T0);
Serial.print(F(" °C     "));
Serial.print(F("Humidity : "));
Serial.print(H0);
Serial.print(" %     ");
Serial.print("Smoke : ");
Serial.print(S0);
Serial.print(" ppm     ");
Serial.print("Fire Class : ");
Serial.print(F0);
Serial.print("\n");

// To set fields with sensor values
ThingSpeak.setField(1, T0);
ThingSpeak.setField(2, H0);
```

```
  ThingSpeak.setField(3, S0);
  ThingSpeak.setField(4, F0);

  // To write to ThingSpeak channel
  int x = ThingSpeak.writeFields(writeChannel, writeAPI);
  delay(15000);

  if (x == 200)
  {
    Serial.println("Channel updated successfully.\n");
  }
  else
  {
    Serial.println("Unable to update channel. HTTP error code " +
String(x));
    Serial.print("\n");
  }

  // To read fields with sensor values
  float T1 = ThingSpeak.readFloatField(readChannel, 1, readAPI);
  float H1 = ThingSpeak.readFloatField(readChannel, 2, readAPI);
  int S1 = ThingSpeak.readIntField(readChannel, 3, readAPI);
  int F1 = ThingSpeak.readIntField(readChannel, 4, readAPI);

  // To read from ThingSpeak channel
  int y = ThingSpeak.getLastReadStatus();
  delay(5000);

  if (y == 200)
  {
    Serial.println("Channel read successfully.\n");
  }
  else
  {
    Serial.println("Unable to read channel. HTTP error code " +
String(y));
    Serial.print("\n");
  }

  // To print all readings of Node 1 on Serial Monitor
  Serial.println("{ Readings from Node 1 }\n");
```

```
Serial.print(F("Temperature : "));
Serial.print(T1);
Serial.print(F(" °C     "));
Serial.print(F("Humidity : "));
Serial.print(H1);
Serial.print(" %     ");
Serial.print("Smoke : ");
Serial.print(S1);
Serial.print(" ppm     ");
Serial.print("Fire Class : ");
Serial.print(F1);
Serial.print("\n");

// To set threshold values of fire
if (T0>38 && S0>800 && F0==0)
{
  Serial.println("* FIRE ON 1ST FLOOR !!! *\n");
  digitalWrite(Buzzer, HIGH);

  // j loop controls brightness & i loop defines LEDs section
  for (int j=0; j<255; j++)
  {
    for (int i=0; i<LEDNUM; i++)
    {
      leds_L[i]=CRGB(j, 0, 0);
      leds_R[i]=CRGB(j, 0, 0);
    }
    FastLED.show();
  }
}
else if (T1>38 && S1>800 && F1==0)
{
  Serial.println("* FIRE ON 2ND FLOOR !!! *\n");
  digitalWrite(Buzzer, HIGH);

  for (int j=0; j<255; j++)
  {
    for (int i=0; i<30; i++)
    {
      leds_L[i]=CRGB(j, 0, 0);
      leds_R[i]=CRGB(j, 0, 0);
```

```
        }
        for (int i=30; i<LEDNUM; i++)
        {
          leds_L[i]=CRGB(0, j, 0);
          leds_R[i]=CRGB(0, j, 0);
        }
        FastLED.show();
      }
    }
    else
    {
      Serial.println("* NO FIRE *\n");
      digitalWrite(Buzzer, LOW);

      for (int j=0; j<255; j++)
      {
        for (int i=0; i<LEDNUM; i++)
        {
          leds_L[i]=CRGB(0, j, 0);
          leds_R[i]=CRGB(0, j, 0);
        }
        FastLED.show();
      }
    }
  }
```

1. Overview

ESP-WROOM-32 is a powerful, generic Wi-Fi+BT+BLE MCU module that targets a wide variety of applications, ranging from low-power sensor networks to the most demanding tasks, such as voice encoding, music streaming and MP3 decoding.

At the core of this module is the ESP32-D0WDQ6 chip*. The chip embedded is designed to be scalable and adaptive. There are two CPU cores that can be individually controlled, and the clock frequency is adjustable from 80 MHz to 240 MHz. The user may also power off the CPU and make use of the low-power coprocessor to constantly monitor the peripherals for changes or crossing of thresholds. ESP32 integrates a rich set of peripherals, ranging from capacitive touch sensors, Hall sensors, low-noise sense amplifiers, SD card interface, Ethernet, high-speed SPI, UART, I2S and I2C.

Note:
* For details on the part number of the ESP32 series, please refer to the document *ESP32 Datasheet*.

The integration of Bluetooth, Bluetooth LE and Wi-Fi ensures that a wide range of applications can be targeted, and that the module is future proof: using Wi-Fi allows a large physical range and direct connection to the internet through a Wi-Fi router, while using Bluetooth allows the user to conveniently connect to the phone or broadcast low energy beacons for its detection. The sleep current of the ESP32 chip is less than 5 μA, making it suitable for battery powered and wearable electronics applications. ESP32 supports a data rate of up to 150 Mbps, and 20.5 dBm output power at the antenna to ensure the widest physical range. As such the chip does offer industry-leading specifications and the best performance for electronic integration, range, power consumption, and connectivity.

The operating system chosen for ESP32 is freeRTOS with LwIP; TLS 1.2 with hardware acceleration is built in as well. Secure (encrypted) over the air (OTA) upgrade is also supported, so that developers can continually upgrade their products even after their release.

Table 2 provides the specifications of ESP-WROOM-32.

Table 2: ESP-WROOM-32 Specifications

Categories	Items	Specifications
Wi-Fi	RF certification	FCC/CE/IC/TELEC/KCC/SRRC/NCC
	Protocols	802.11 b/g/n/e/i (802.11n up to 150 Mbps)
		A-MPDU and A-MSDU aggregation and 0.4 μs guard interval support
	Frequency range	2.4 ~ 2.5 GHz
Bluetooth	Protocols	Bluetooth v4.2 BR/EDR and BLE specification
	Radio	NZIF receiver with -97 dBm sensitivity
		Class-1, class-2 and class-3 transmitter
		AFH
	Audio	CVSD and SBC

Categories	Items	Specifications
Hardware	Module interface	SD card, UART, SPI, SDIO, I2C, LED PWM, Motor PWM, I2S, IR
		GPIO, capacitive touch sensor, ADC, DAC, LNA pre-amplifier
	On-chip sensor	Hall sensor, temperature sensor
	On-board clock	40 MHz crystal
	Operating voltage/Power supply	2.3 ~ 3.6V
	Operating current	Average: 80 mA
	Minimum current delivered by power supply	500 mA
	Operating temperature range	-40°C ~ +85°C
	Ambient temperature range	Normal temperature
	Package size	18±0.2 mm x 25.5±0.2 mm x 3.1±0.15 mm
Software	Wi-Fi mode	Station/SoftAP/SoftAP+Station/P2P
	Security	WPA/WPA2/WPA2-Enterprise/WPS
	Encryption	AES/RSA/ECC/SHA
	Firmware upgrade	UART Download / OTA (download and write firmware via network or host)
	Software development	Supports Cloud Server Development / SDK for custom firmware development
	Network protocols	IPv4, IPv6, SSL, TCP/UDP/HTTP/FTP/MQTT
	User configuration	AT instruction set, cloud server, Android/iOS app

2. Pin Definitions

2.1 Pin Layout

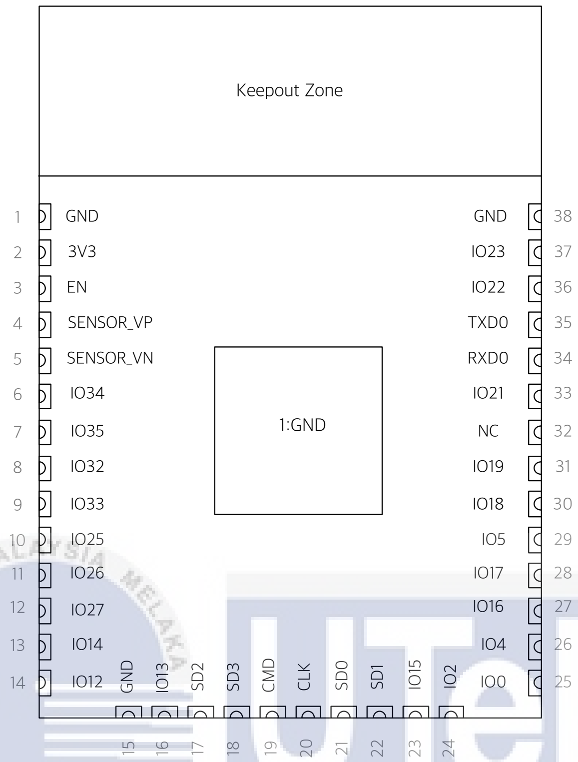


Figure 1: Pin Layout of ESP-WROOM-32 from Front View

Note:
There is a large ground pad on the bottom of ESP-WROOM-32 and it is recommended that users connect it to ground for better heat dissipation.

2.2 Pin Description

ESP-WROOM-32 has 39 pins. See pin definitions in Table 3.

Table 3: Pin Definitions

Name	No.	Type	Function
GND	1	P	Ground
3V3	2	P	Power supply.
EN	3	I	Chip-enable signal. Active high.
SENSOR_VP	4	I	GPIO36, SENSOR_VP, ADC_H, ADC1_CH0, RTC_GPIO0
SENSOR_VN	5	I	GPIO39, SENSOR_VN, ADC1_CH3, ADC_H, RTC_GPIO3
IO34	6	I	GPIO34, ADC1_CH6, RTC_GPIO4
IO35	7	I	GPIO35, ADC1_CH7, RTC_GPIO5
IO32	8	I/O	GPIO32, XTAL_32K_P (32.768 kHz crystal oscillator input), ADC1_CH4, TOUCH9, RTC_GPIO9

Name	No.	Type	Function
IO33	9	I/O	GPIO33, XTAL_32K_N (32.768 kHz crystal oscillator output), ADC1_CH5, TOUCH8, RTC_GPIO8
IO25	10	I/O	GPIO25, DAC_1, ADC2_CH8, RTC_GPIO6, EMAC_RXD0
IO26	11	I/O	GPIO26, DAC_2, ADC2_CH9, RTC_GPIO7, EMAC_RXD1
IO27	12	I/O	GPIO27, ADC2_CH7, TOUCH7, RTC_GPIO17, EMAC_RX_DV
IO14	13	I/O	GPIO14, ADC2_CH6, TOUCH6, RTC_GPIO16, MTMS, HSPICLK, HS2_CLK, SD_CLK, EMAC_TXD2
IO12	14	I/O	GPIO12, ADC2_CH5, TOUCH5, RTC_GPIO15, MTDI, HSPIQ, HS2_DATA2, SD_DATA2, EMAC_TXD3
GND	15	P	Ground
IO13	16	I/O	GPIO13, ADC2_CH4, TOUCH4, RTC_GPIO14, MTCK, HSPID, HS2_DATA3, SD_DATA3, EMAC_RX_ER
SHD/SD2*	17	I/O	GPIO9, SD_DATA2, SPIHD, HS1_DATA2, U1RXD
SWP/SD3*	18	I/O	GPIO10, SD_DATA3, SPIWP, HS1_DATA3, U1TXD
SCS/CMD*	19	I/O	GPIO11, SD_CMD, SPICS0, HS1_CMD, U1RTS
SCK/CLK*	20	I/O	GPIO6, SD_CLK, SPICLK, HS1_CLK, U1CTS
SDO/SD0*	21	I/O	GPIO7, SD_DATA0, SPIQ, HS1_DATA0, U2RTS
SDI/SD1*	22	I/O	GPIO8, SD_DATA1, SPID, HS1_DATA1, U2CTS
IO15	23	I/O	GPIO15, ADC2_CH3, TOUCH3, MTDO, HSPICS0, RTC_GPIO13, HS2_CMD, SD_CMD, EMAC_RXD3
IO2	24	I/O	GPIO2, ADC2_CH2, TOUCH2, RTC_GPIO12, HSPIWP, HS2_DATA0, SD_DATA0
IO0	25	I/O	GPIO0, ADC2_CH1, TOUCH1, RTC_GPIO11, CLK_OUT1, EMAC_TX_CLK
IO4	26	I/O	GPIO4, ADC2_CH0, TOUCH0, RTC_GPIO10, HSPIHD, HS2_DATA1, SD_DATA1, EMAC_TX_ER
IO16	27	I/O	GPIO16, HS1_DATA4, U2RXD, EMAC_CLK_OUT
IO17	28	I/O	GPIO17, HS1_DATA5, U2TXD, EMAC_CLK_OUT_180
IO5	29	I/O	GPIO5, VSPICS0, HS1_DATA6, EMAC_RX_CLK
IO18	30	I/O	GPIO18, VSPICLK, HS1_DATA7
IO19	31	I/O	GPIO19, VSPIQ, U0CTS, EMAC_TXD0
NC	32	-	-
IO21	33	I/O	GPIO21, VSPIHD, EMAC_TX_EN
RXD0	34	I/O	GPIO3, U0RXD, CLK_OUT2
TXD0	35	I/O	GPIO1, U0TXD, CLK_OUT3, EMAC_RXD2
IO22	36	I/O	GPIO22, VSPIWP, U0RTS, EMAC_TXD1
IO23	37	I/O	GPIO23, VSPID, HS1_STROBE
GND	38	P	Ground
GND	39	P	Ground

Note:
* Pins SCK/CLK, SDO/SD0, SDI/SD1, SHD/SD2, SWP/SD3 and SCS/CMD, namely, GPIO6 to GPIO11 are connected to the integrated SPI flash integrated on ESP-WROOM-32 and are not recommended for other uses.

2.3 Strapping Pins

Please refer to ESP-WROOM-32 schematics.

ESP32 has five strapping pins:

- MTDI
- GPIO0
- GPIO2
- MTDO
- GPIO5

Software can read the value of these five bits from the register ”GPIO_STRAPPING”.

During the chip power-on reset, the latches of the strapping pins sample the voltage level as strapping bits of ”0” or ”1”, and hold these bits until the chip is powered down or shut down. The strapping bits configure the device boot mode, the operating voltage of VDD_SDIO and other system initial settings.

Each strapping pin is connected with its internal pull-up/pull-down during the chip reset. Consequently, if a strapping pin is unconnected or the connected external circuit is high-impendence, the internal weak pull-up/pull-down will determine the default input level of the strapping pins.

To change the strapping bit values, users can apply the external pull-down/pull-up resistances, or apply the host MCU's GPIOs to control the voltage level of these pins when powering on ESP32.

After reset, the strapping pins work as the normal functions pins.

Refer to Table 4 for detailed boot modes configuration by strapping pins.

Table 4: Strapping Pins

Voltage of Internal LDO (VDD_SDIO)					
Pin	Default	3.3V		1.8V	
MTDI	Pull-down	0		1	
Booting Mode					
Pin	Default	SPI Boot		Download Boot	
GPIO0	Pull-up	1		0	
GPIO2	Pull-down	Don't-care		0	
Debugging Log on U0TXD During Booting					
Pin	Default	U0TXD Toggling		U0TXD Silent	
MTDO	Pull-up	1		0	
Timing of SDIO Slave					
Pin	Default	Falling-edge Input Falling-edge Output	Falling-edge Input Rising-edge Output	Rising-edge Input Falling-edge Output	Rising-edge Input Rising-edge Output
MTDO	Pull-up	0	0	1	1
GPIO5	Pull-up	0	1	0	1

Note:

Firmware can configure register bits to change the settings of ”Voltage of Internal LDO (VDD_SDIO)” and ”Timing of SDIO Slave” after booting.

5. Electrical Characteristics

Note:
The specifications in this chapter have been tested under the following general condition: VDD = 3.3V, T_A = 27°C, unless otherwise specified.

5.1 Absolute Maximum Ratings

Table 8: Absolute Maximum Ratings

Parameter	Symbol	Min	Typ	Max	Unit
Power supply[1]	VDD	2.3	3.3	3.6	V
Minimum current delivered by power supply	I_{VDD}	0.5	-	-	A
Input low voltage	V_{IL}	-0.3	-	0.25×V_{IO}[2]	V
Input high voltage	V_{IH}	0.75×V_{IO}[2]	-	V_{IO}[2]+0.3	V
Input leakage current	I_{IL}	-	-	50	nA
Input pin capacitance	C_{pad}	-	-	2	pF
Output low voltage	V_{OL}	-	-	0.1×V_{IO}[2]	V
Output high voltage	V_{OH}	0.8×V_{IO}[2]	-	-	V
Maximum output drive capability	I_{MAX}	-	-	40	mA
Storage temperature range	T_{STR}	-40	-	85	°C
Operating temperature range	T_{OPR}	-40	-	85	°C

1. The power supplies include VDDA, VDD3P3, VDD3P3_RTC, VDD3P3_CPU, VDD_SDIO. The VDD_SDIO also supports 1.8V mode.
2. V_{IO} is the power supply for a specific pad. More details can be found in the ESP32 Datasheet, Appendix IO_MUX. For example, the power supply for SD_CLK is the VDD_SDIO.

5.2 Wi-Fi Radio

Table 9: Wi-Fi Radio Characteristics

Description	Min	Typical	Max	Unit
Input frequency	2412	-	2484	MHz
Output impedance	-	30+j10	-	Ω
Input reflection	-	-	-10	dB
Tx power				
Output power of PA for 72.2 Mbps	13	14	15	dBm
Output power of PA for 11b mode	19.5	20	20.5	dBm
Sensitivity				
DSSS, 1 Mbps	-	-98	-	dBm
CCK, 11 Mbps	-	-91	-	dBm
OFDM, 6 Mbps	-	-93	-	dBm

Description	Min	Typical	Max	Unit
OFDM, 54 Mbps	-	-75	-	dBm
HT20, MCS0	-	-93	-	dBm
HT20, MCS7	-	-73	-	dBm
HT40, MCS0	-	-90	-	dBm
HT40, MCS7	-	-70	-	dBm
MCS32	-	-89	-	dBm
Adjacent channel rejection				
OFDM, 6 Mbps	-	37	-	dB
OFDM, 54 Mbps	-	21	-	dB
HT20, MCS0	-	37	-	dB
HT20, MCS7	-	20	-	dB

5.3 BLE Radio

5.3.1 Receiver

Table 10: Receiver Characteristics – BLE

Parameter	Conditions	Min	Typ	Max	Unit
Sensitivity @30.8% PER	-	-	-97	-	dBm
Maximum received signal @30.8% PER	-	0	-	-	dBm
Co-channel C/I	-	-	+10	-	dB
Adjacent channel selectivity C/I	F = F0 + 1 MHz	-	-5	-	dB
	F = F0 - 1 MHz	-	-5	-	dB
	F = F0 + 2 MHz	-	-25	-	dB
	F = F0 - 2 MHz	-	-35	-	dB
	F = F0 + 3 MHz	-	-25	-	dB
	F = F0 - 3 MHz	-	-45	-	dB
Out-of-band blocking performance	30 MHz ~ 2000 MHz	-10	-	-	dBm
	2000 MHz ~ 2400 MHz	-27	-	-	dBm
	2500 MHz ~ 3000 MHz	-27	-	-	dBm
	3000 MHz ~ 12.5 GHz	-10	-	-	dBm
Intermodulation	-	-36	-	-	dBm

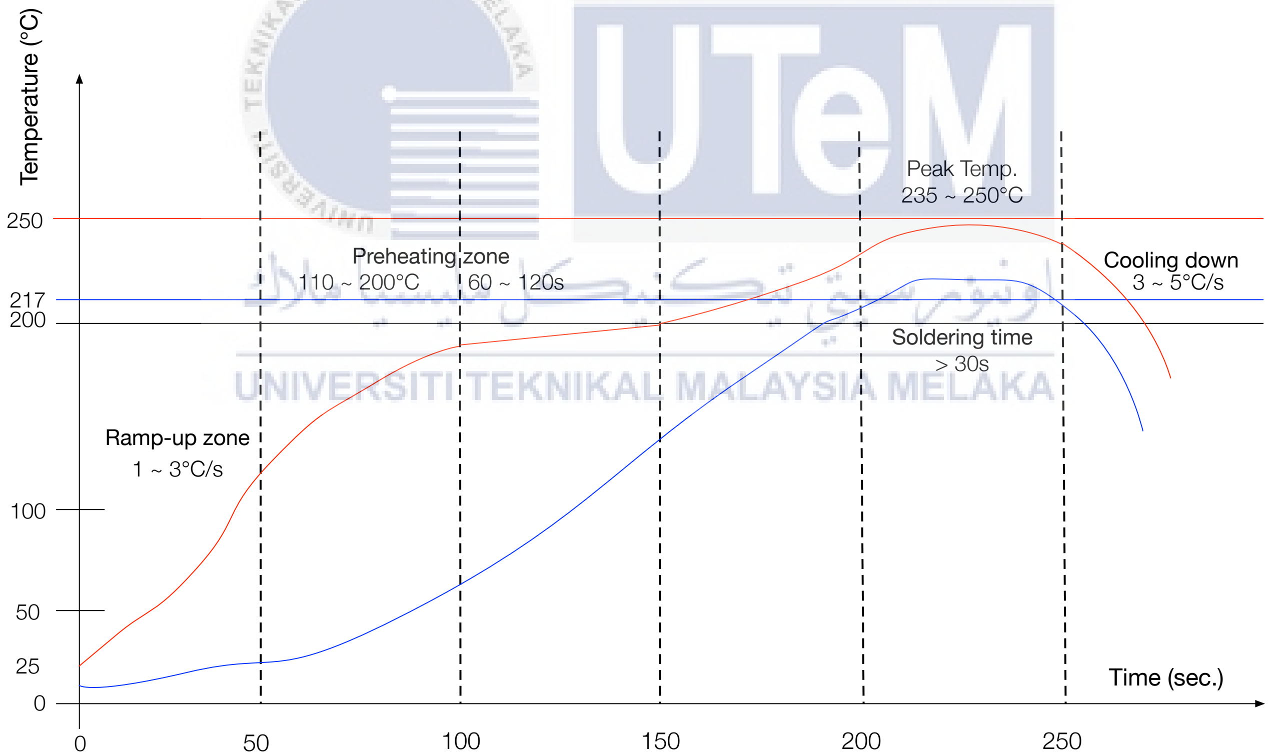
5.3.2 Transmitter

Table 11: Transmitter Characteristics - BLE

Parameter	Conditions	Min	Typ	Max	Unit
RF transmit power	-	-	0	-	dBm
Gain control step	-	-	±3	-	dBm
RF power control range	-	-12	-	+12	dBm

Parameter	Conditions	Min	Typ	Max	Unit
Adjacent channel transmit power	F = F0 + 1 MHz	-	-14.6	-	dBm
	F = F0 - 1 MHz	-	-12.7	-	dBm
	F = F0 + 2 MHz	-	-44.3	-	dBm
	F = F0 - 2 MHz	-	-38.7	-	dBm
	F = F0 + 3 MHz	-	-49.2	-	dBm
	F = F0 - 3 MHz	-	-44.7	-	dBm
	F = F0 + > 3 MHz	-	-50	-	dBm
	F = F0 - > 3 MHz	-	-50	-	dBm
$\Delta f1_{avg}$	-	-	-	265	kHz
$\Delta f2_{max}$	-	247	-	-	kHz
$\Delta f2_{avg}/\Delta f1_{avg}$	-	-	-0.92	-	-
ICFT	-	-	-10	-	kHz
Drift rate	-	-	0.7	-	kHz/50 μs
Drift	-	-	2	-	kHz

5.4 Reflow Profile



Ramp-up zone (升温区): Temp. <150°C, Time 60 ~ 90s, Ramp-up rate 1 ~ 3°C/s.
Preheating zone (预热恒温区): Temp. 150 ~ 200°C, Time 60 ~ 120s, Ramp-up rate 0.3 ~ 0.8°C/s.
Reflow soldering zone (回流焊接区): Peak Temp. 235 ~ 250°C (<245°C recommended), Time 30 ~ 70s.
Cooling down zone (冷却区): Temp. 217 ~ 170°C, Ramp-down rate 3 ~ 5°C/s.
Sn&Ag&Cu Lead-free solder (SAC305)/焊料为锡银铜合金无铅焊料

Figure 2: Reflow Profile

6. Schematics

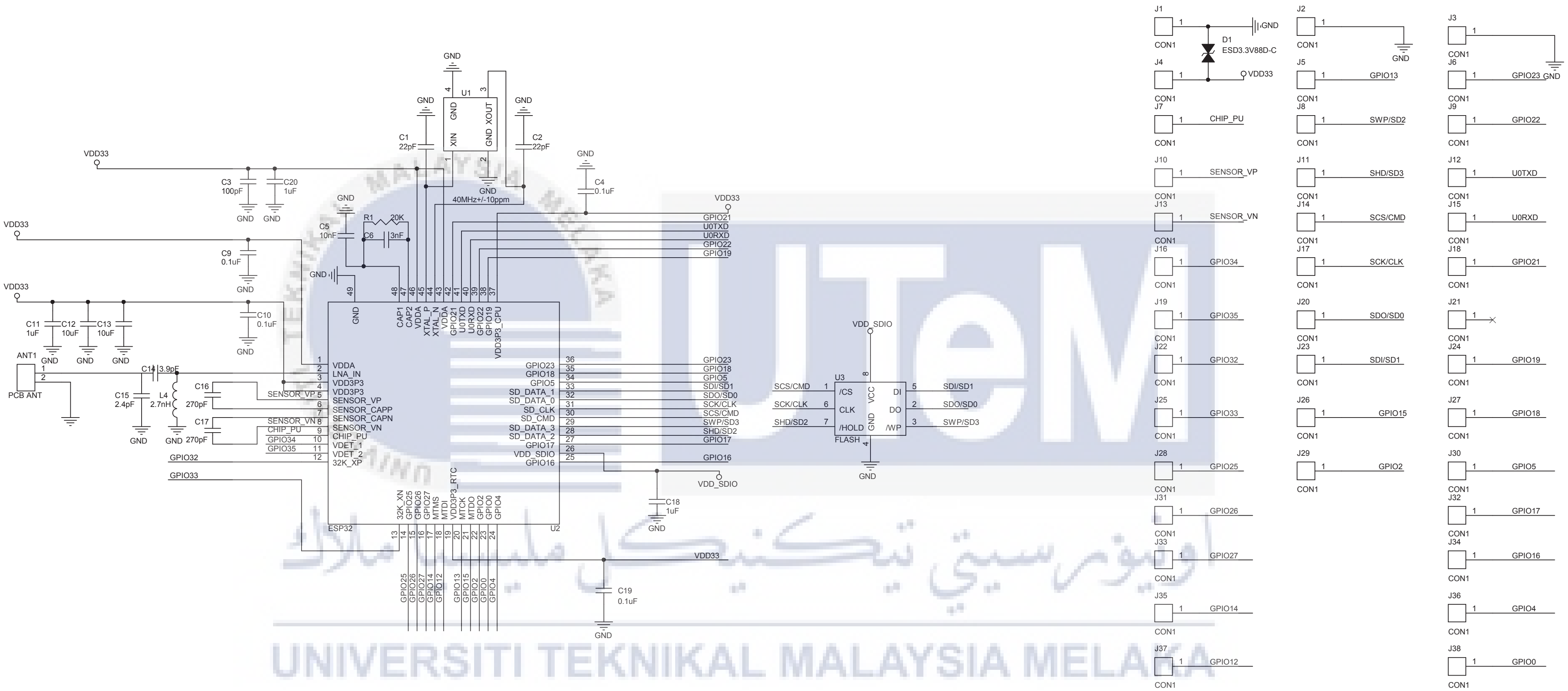
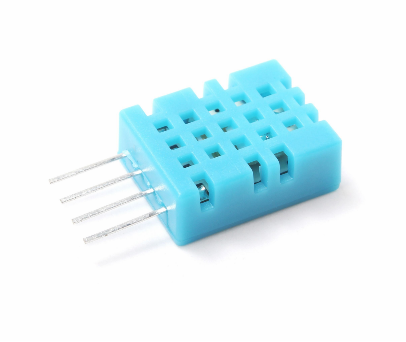


Figure 3: ESP-WROOM-32 Schematics



Digital relative humidity & temperature sensor DHT11

1. Feature & Application:

*Good precision
*Resistive type
*Full range temperature compensated
*Relative humidity and temperature measurement
*Calibrated digital signal
*Outstanding long-term stability
*Extra components not needed
*Long transmission distance, up to 100 meters
*Low power consumption
*4 pins packaged and fully interchangeable

2. Description:

DHT11 output calibrated digital signal. It applys exclusive digital-signal-collecting-technique and humidity sensing technology, assuring its reliability and stability. Its sensing elements is connected with 8-bit single-chip computer.

Every sensor of this model is temperature compensated and calibrated in accurate calibration chamber and the calibration-coefficient is saved in type of programme in OTP memory, when the sensor is detecting, it will cite coefficient from memory.

Small size & low consumption & long transmission distance(100m) enable DHT11 to be suited in all kinds of harsh application occasions. Single-row packaged with four pins, making the connection very convenient.

3. Technical Specification:

Model	DHT11	
Power supply	3.3-5.5V DC	
Output signal	digital signal via Aosong 1-wire bus	
Sensing element	Polymer humidity resistor	
Operating range	humidity 20-90%RH;	temperature 0~50Celsius
Accuracy	**humidity +-5%RH**;	temperature +-2Celsius
Resolution or sensitivity	humidity 1%RH;	temperature 1Celsius
Repeatability	humidity +-2%RH;	temperature +-1Celsius
Humidity hysteresis	+-1%RH	
Long-term Stability	+-1%RH/year	
Interchangeability	fully interchangeable	

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

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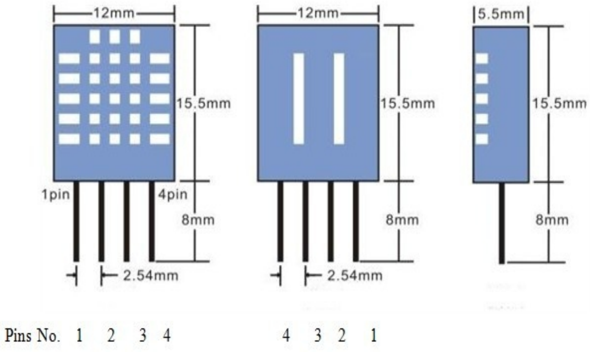
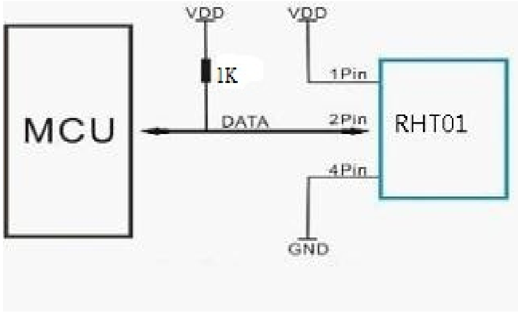


Front view Back view Side elevation

5. Electrical connection diagram:



6. Operating specifications:

(1) Power and Pins

Power's voltage should be 3.3-5.5V DC. When power is supplied to sensor, don't send any instruction to the sensor within one second to pass unstable status. One capacitor valued 100nF can be added between VDD and GND for wave filtering.

(2) Communication and signal

Aosong 1-wire bus is used for communication between MCU and DHT11. (Aosong 1-wire bus is specially designed by Aosong Electronics Co., Ltd. , it's different from Maxim/Dallas 1-wire bus, so it's incompatible with Dallas 1-wire bus.)

Illustration of Aosong 1-wire bus:

DATA=16 bits RH data+16 bits Temperature data+8 bits check-sum

Example: MCU has received 40 bits data from DHT11 as

0010 0001	**0000 0000**	**0001 1010**	**0000 0000**	**0011 1011**
Integral part of RH	Decimal part of RH	Integral part of T	Decimal part of T	check sum

Remarks: The decimal part of RH and T is always 0000 0000.

Here we convert integral part of RH from binary system to decimal system,

0010 0001 → 33

Binary system Decimal system, **RH=33%RH**

Here we convert integral part of T from binary system to decimal system,

0001 1010 → 26

Binary system Decimal system, **T=26 Celsius**

Sum=0010 0001+0000 0000+0001 1010+0000 0000=0011 1011

Check-sum=the last 8 bits of Sum=0011 1011

When MCU send start signal, DHT11 change from standby-status to running-status. When MCU finishs sending the start signal, DHT11 will send response signal of 40-bit data that reflect the relative humidity and temperature to MCU. Without start signal from MCU, DHT11 will not give response signal to MCU. One start signal for one response data from DHT11 that reflect the relative humidity and temperature. DHT11 will change to standby status

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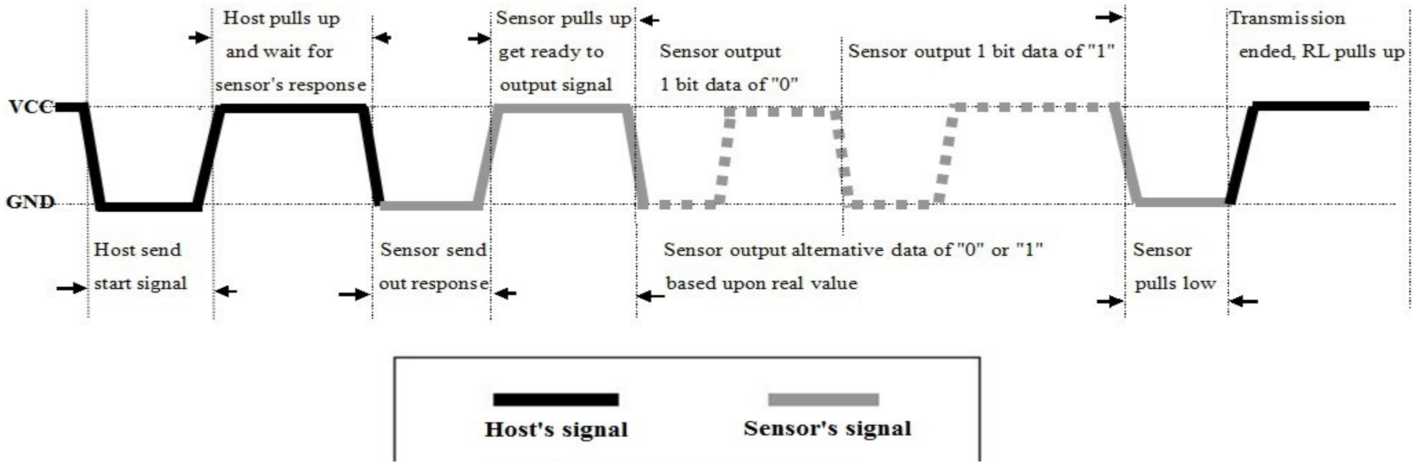
when data collecting finished if it don't receive start signal from MCU again.

See below figure for overall communication process, **the interval of whole process must beyond 2 seconds.**



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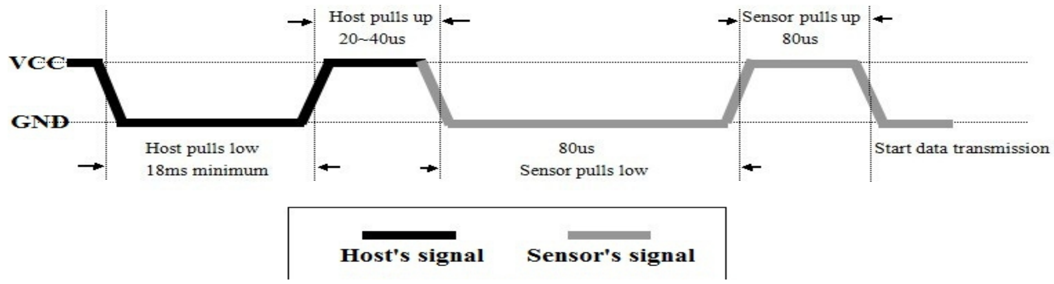
1) Step 1: MCU send out start signal to DHT11 and DHT11 send response signal to MCU

Data-bus's free status is high voltage level. When communication between MCU and DHT11 begins, MCU will pull low data-bus and this process must beyond at least 1~10ms to ensure DHT11 could detect MCU's signal, then MCU will pulls up and wait 20-40us for DHT11's response.

When DHT11 detect the start signal, DHT11 will pull low the bus 80us as response signal, then DHT11 pulls up 80us for preparation to send data. See below figure:



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2). Step 2: DHT11 send data to MCU

When DHT11 is sending data to MCU, every bit's transmission begin with low-voltage-level that last 50us, the following high-voltage-level signal's length decide the bit is "1" or "0". See below figures:

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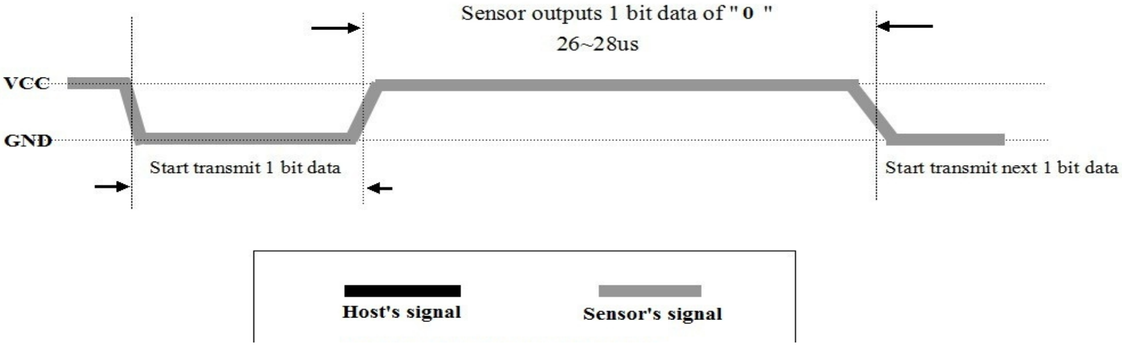
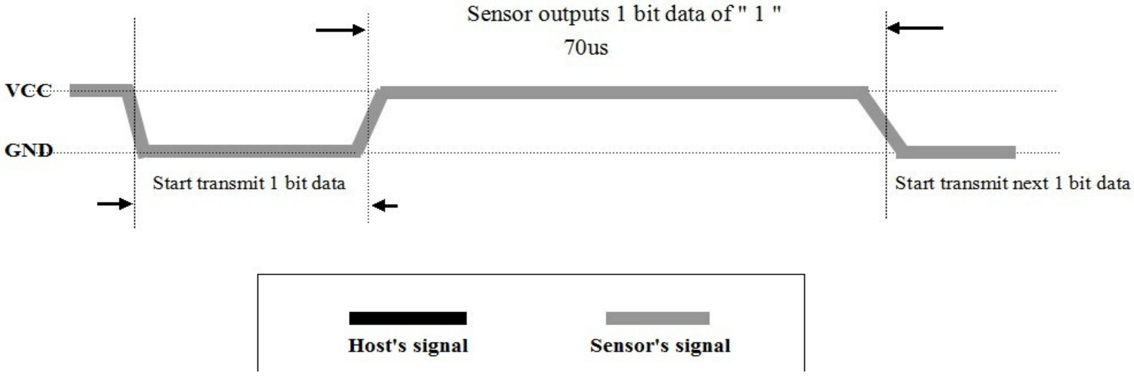




Attention:

If signal from DHT11 is always high-voltage-level, it means DHT11 is not working properly, please check the electrical connection status.

7. Electrical Characteristics:

Items	Condition	Min	Typical	Max	Unit
Power supply	DC	3.3	5	6	V
Current supply	Measuring	1		1.5	mA
	Stand-by	40	Null	50	uA
Collecting period	Second		2		Second

8. Error and sources of error:

Measure values maybe influenced by follow factors:

Humidity errors

Equilibration time too short, steam, water sprays, dripping water or condensation at the sensor, etc.

Temperature errors

Equilibration time too short, cold or hot outside wall, sunlights, heating elements, etc.

MQ-2 Semiconductor Sensor for Combustible Gas

Sensitive material of MQ-2 gas sensor is SnO_2, which with lower conductivity in clean air. When the target combustible gas exist, The sensor's conductivity is more higher along with the gas concentration rising. Please use simple electrocircuit, Convert change of conductivity to correspond output signal of gas concentration.

MQ-2 gas sensor has high sensitity to LPG, Propane and Hydrogen, also could be used to Methane and other combustible steam, it is with low cost and suitable for different application.

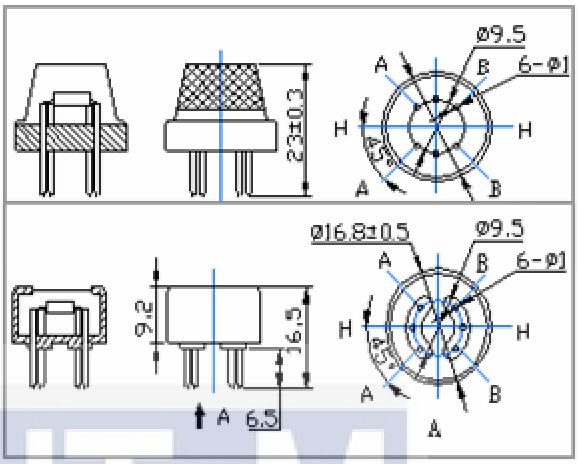
Character

*Good sensitivity to Combustible gas in wide range
* High sensitivity to LPG, Propane and Hydrogen
* Long life and low cost
* Simple drive circuit

Application

* Domestic gas leakage detector
* Industrial Combustible gas detector
* Portable gas detector

Configuration

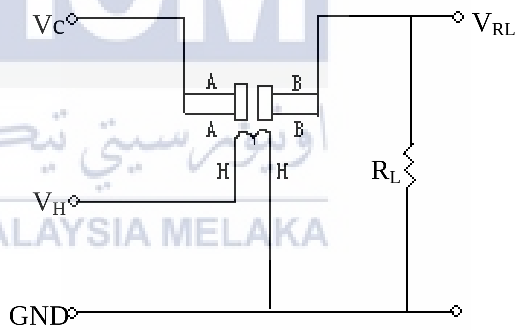


Technical Data

Model No.			MQ-2
Sensor Type			Semiconductor
Standard Encapsulation			Bakelite (Black Bakelite)
Detection Gas			Combustible gas and smoke
Concentration			300-10000ppm (Combustible gas)
Circuit	Loop Voltage	V_c	≤24V DC
	Heater Voltage	V_H	5.0V±0.2V ACorDC
	Load Resistance	R_L	Adjustable
Character	Heater Resistance	R_H	31Ω±3Ω（Room Tem.）
	Heater consumption	P_H	≤900mW
	Sensing Resistance	R_s	2KΩ-20KΩ(in 2000ppm C_3H_8)
	Sensitivity	S	Rs(in air)/Rs(1000ppm isobutane)≥5
	Slope	α	≤0.6($R_{5000ppm}/R_{3000ppm}$ CH_4)
Condition	Tem. Humidity		20℃±2℃；65%±5%RH
	Standard test circuit		Vc:5.0V±0.1V； V_H: 5.0V±0.1V
	Preheat time		Over 48 hours

Basic test loop

T



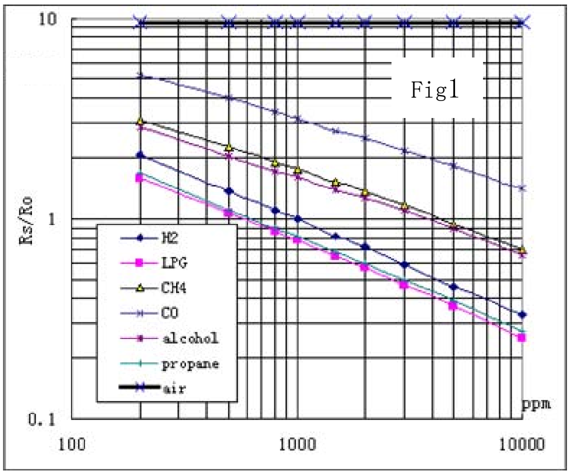
The above is basic test circuit of the sensor. The sensor need to be put 2 voltage, heater voltage（VH） and test voltage（VC）. VH used to supply certified working temperature to the sensor, while VC used to detect voltage (VRL) on load resistance （RL） whom is in series with sensor. The sensor has light polarity, Vc need DC power. VC and VH could use same power circuit with precondition to assure performance of sensor. In order to make the sensor with better performance, suitable RL value is needed:

Power of Sensitivity body(Ps):

$Ps=Vc^2 \times Rs/(Rs+RL)^2$

Resistance of sensor(Rs): Rs=(Vc/VRL-1)×RL

Sensitivity Characteristics



Influence of Temperature/Humidity

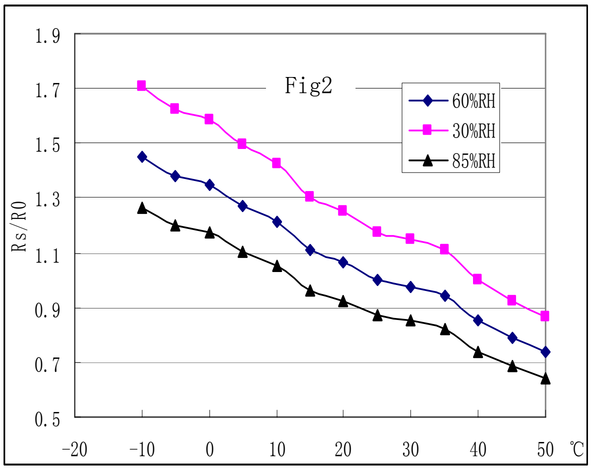


Fig.1 shows the typical sensitivity characteristics of the MQ-2, ordinate means resistance ratio of the sensor **(**Rs/Ro**)**, abscissa is concentration of gases. Rs means resistance in different gases, Ro means resistance of sensor in 1000ppm Hyrogen. All test are under standard test conditions.

Fig.2 shows the typical temperature and humidity characteristics. Ordinate means resistance ratio of the sensor (Rs/Ro), Rs means resistance of sensor in 1000ppm Butane under different tem. and humidity. Ro means resistance of the sensor in environment of 1000ppm Methane, 20℃/65%RH

Structure and configuration

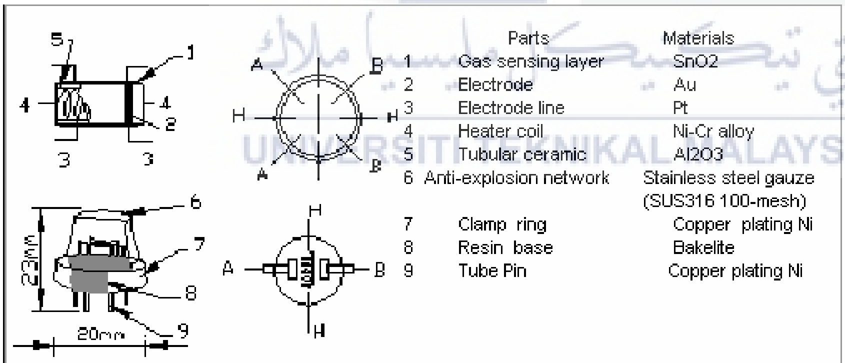


Fig. 3

Structure and configuration of MQ-2 gas sensor is shown as Fig. 3, sensor composed by micro AL2O3 ceramic tube, Tin Dioxide (SnO2) sensitive layer, measuring electrode and heater are fixed into a crust made by plastic and stainless steel net. The heater provides necessary work conditions for work of sensitive components. The enveloped MQ-2 have 6 pin, 4 of them are used to fetch signals, and other 2 are used for providing heating current.

Technical Data Sheet

Features

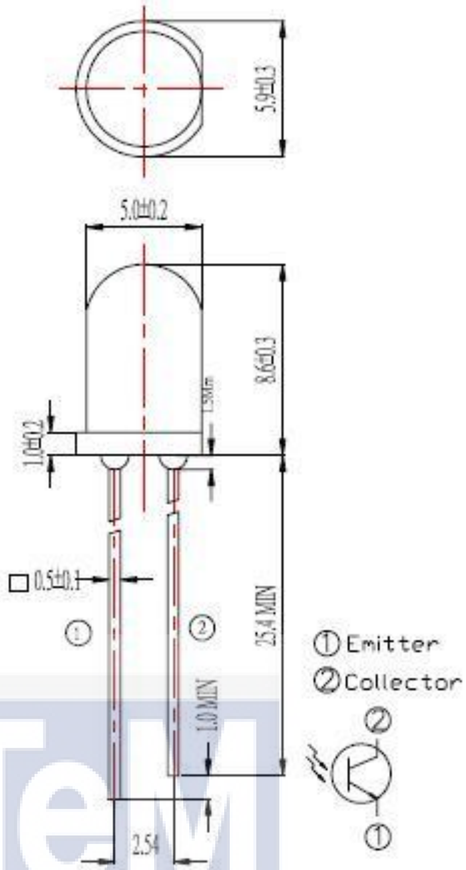
- Fast response tine
- High photo sensitivity
- Pb free
- This product itself will remain within RoHS conpliant version.

Descriptions

- YG1006 is a high speed and high sensitive NPNsiicon phototransistor in a standard5mm package.

Dueto its black epoxy the device is sensitive to infrared radiation.

Package Dimensions



Note : 1. All dimensions are in millimeters

2. Tolerances unless dimensions ±0.25mm

Absoulute Maximum Ratings (Ta=25℃)

Parameter	Symbol	rating	units
Collector-Emitter Voltage	V_{CEO}	30	V
Emitter-Collector-Voltage	V_{ECO}	5	V
Collector Current	Ic	20	mA
Operating Temperature	Topr	-25～+85℃	℃
Storage Temperature	Tstg	-40+85℃	℃
Lead Soldering Temperature	Tsol	260	℃
Power Dissipation at (or below) 25℃ FreeAir Temperature	Pc	75	mW

Electro-Opticai Characteristcs (Ta=25℃)

Parameter	Symbol	Condition	Min.	Typ.	Max.	Units
Collector-Emitter Breakdown Voltage	BV_{CEO}	Ic=100μA Ee=0mW/C ㎡	30	---	---	V
Emitter-Collector Saturation Voltage	BV_{ECO}	IE=100μA Ee=0mW/C ㎡	5	---	---	V
Collector-Emitter Saturation Voltage	$V_{CE(sat)}$	Ic=2mA Ee=1mW/C ㎡	---	---	0.4	V
Rise Time	tf	V_{CE}=5V Ic=1mA RL=1000Ω	---	15	---	μS
Fall Time	tf		---	15	---	
Collector Dark Current	I_{CEO}	Ee=0mW/C ㎡ V_{CE}=20V	---	----	100	nA
On State Collector Current	Ic(on)	Ee=1mW/ C ㎡ V_{CE}=5V	1.77	----	7.07	mA
Wavelength of Peak Sensitivity	λP	---	---	940	---	nm
Rang of Spectral Bandwidth	λ0.5	---	---	760-1100	---	nm

Rankings

Parameter	Symbol	Min	Max	Unit	Test Condition
	Ic(on)			mA	V_{CE}=5V Ee=1mW/ C ㎡
J		1.77	3.61		
K		2.67	5.07		
L		4.18	7.07		

Typical Electro-Optical Characteristics Curves

Fig.1Collector Power Dissipation vs.
Ambient Temperature

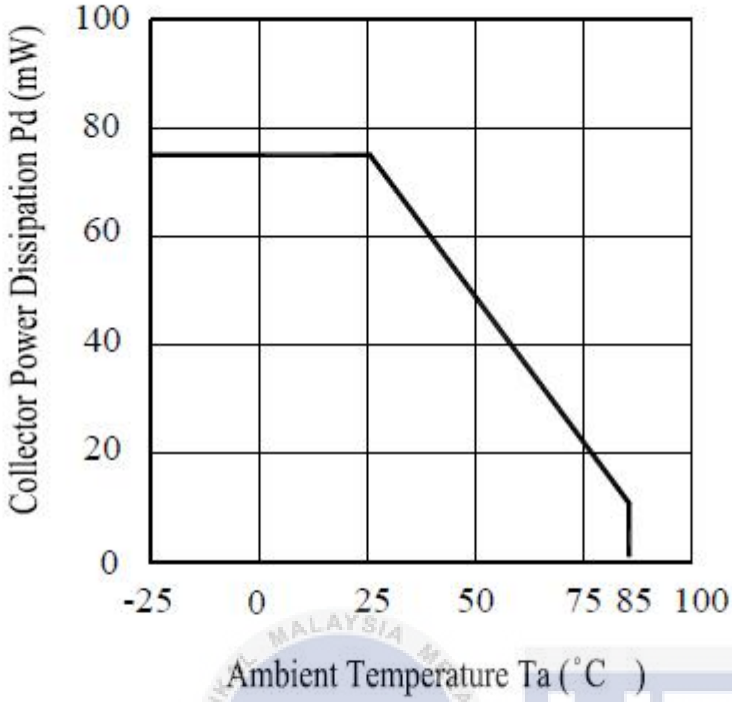


Fig.2 Spectral Sensitivity

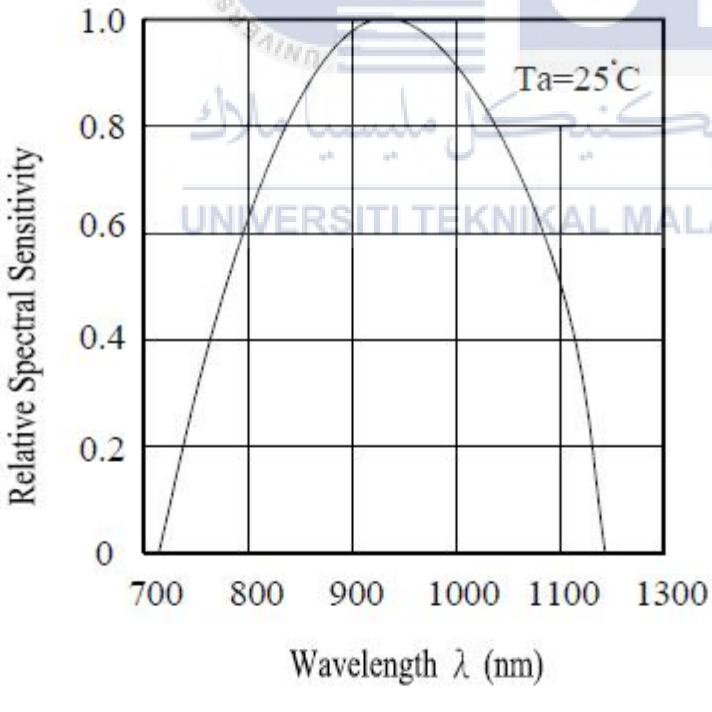


Fig.3 Relative Collector Current vs.
Ambient Temperature

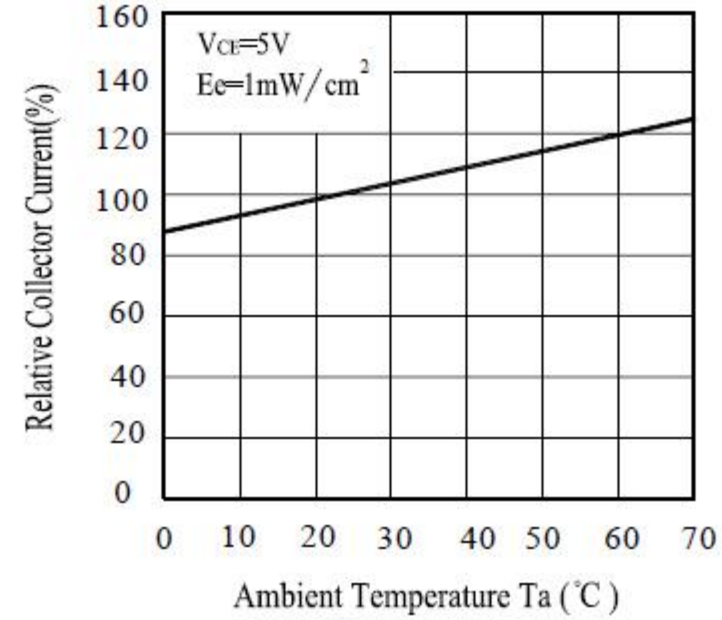
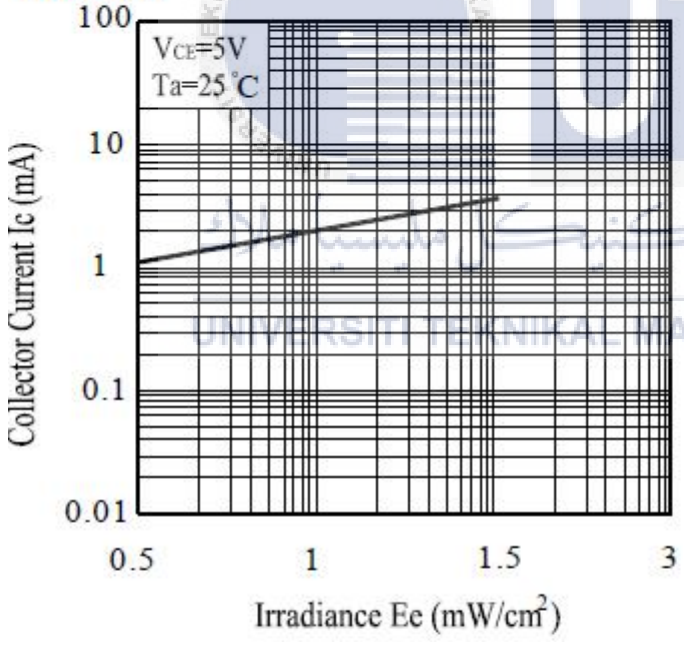


Fig.4 Collector Current vs.
Irradiance



Typical Electro-Optical Characteristecs

Fig.5 Collector Dark Current vs.
Ambient Temperature

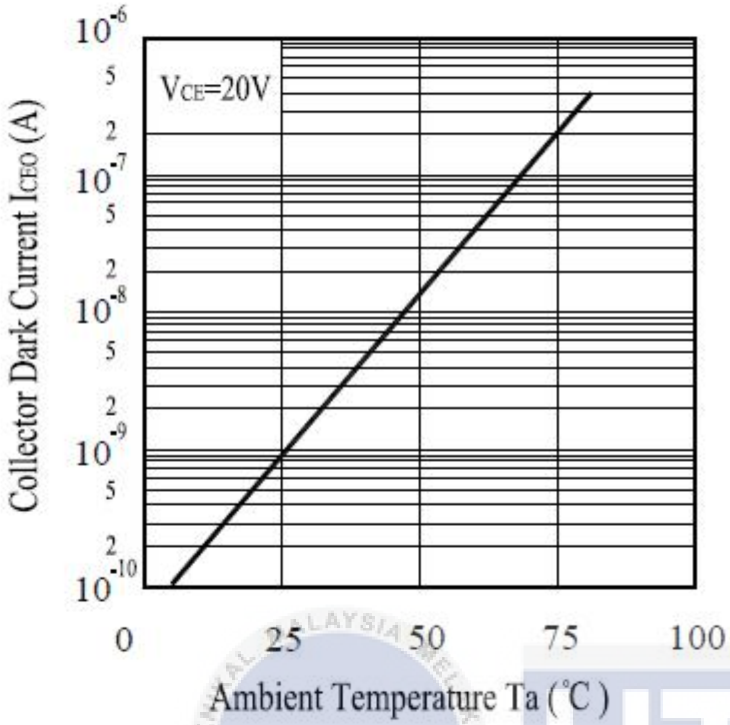
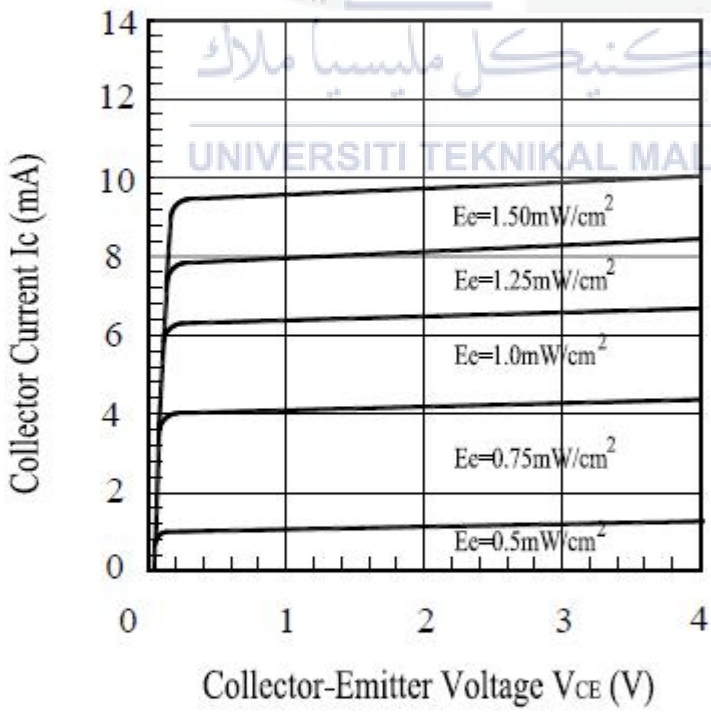


Fig.6 Collector Current vs.
Collector-Emitter Voltage



Reliability Test Item And Condition

The reliability of products shall be satisfied with items listed below.

Confidence level：90%

LTPD：10%

NO.	Item	Test Conditions	Test Hours/ Cycles	Sample Sizes	Failure Judgement Criteria	Ac/Re
1	Solder Heat	TEMP.：260℃±5℃	10secs	22pcs		0/1
2	Temperature Cycle	H : +100℃ 15mins ↕ 5mins L : -40℃ 15mins	300Cycles	22pcs	$I_{C(ON)} \leq L \times 0.8$	0/1
3	Thermal Shock	H :+100℃ 5mins ↕ 10secs L :-10℃ 5mins	300Cycles	22pcs	L：the initial test value	0/1
4	High Temperature Storage	TEMP.：+100℃	1000hrs	22pcs		0/1
5	Low Temperature Storage	TEMP.：-40℃	1000hrs	22pcs		0/1
6	DC Operating Life	V_{CE}=5V	1000hrs	22pcs		0/1
7	High Temperature/ High Humidity	85℃ / 85% R.H	1000hrs	22pcs		0/1

SK6812

Technical Data Sheet

Product Overview

SK6812 is a set of smart control circuit and a light emitting circuit in one of the controlled LED source. The outer type is the same with a 5050LED chip, each element is a pixel. Pixels contained within the intelligent digital interface data latch signal shaping amplification circuit, power supply circuit, a built-in constant current circuit, high precision RC oscillator, the output is driven by the patented PWM technology, effectively guarantee the pixels in the color of the light high consistency.

Data protocol using unipolar NRZ communication mode, the pixel is reset after the end of DIN, accept the data transmitted from the controller to the 24bit, the first to send data by the first pixel to pixel extraction, internal data latch, the remaining data after the internal plastic the processing circuit after shaping amplification through the DO port output began to turn to the next cascade of pixels, each pixel through a transmission signal, reduce. Pixel using automatic shaping forwarding technology, makes the number of cascade without signal transmission limit of the pixel, only limited signal transmission speed. The

LED has a low driving voltage, environmental protection and energy saving, high brightness, scattering angle, good consistency, low power, long life and so on. The control circuit is integrated in the LED above, more simple circuit, small volume, easy installation.

Main Application Field:

- Full color LED string light, LED full color module, LED super hard and soft lights, LED guardrail tube, LED appearance / scene lighting
- LED point light, LED pixel screen, LED shaped screen, a variety of electronic products, electrical equipment etc..

SK6812

Technical Data Sheet

Description:

● Top SMD internal integrated high quality external control line serial cascade constant current IC;

● control circuit and the RGB chip in SMD 5050 components, to form a complete control of pixel, color mixing uniformity and consistency;

● built-in data shaping circuit, a pixel signal is received after wave shaping and output waveform distortion will not guarantee a line;

● The built-in power on reset and reset circuit, the power does not work;

● gray level adjusting circuit (256 level gray scale adjustable);

● red drive special treatment, color balance;

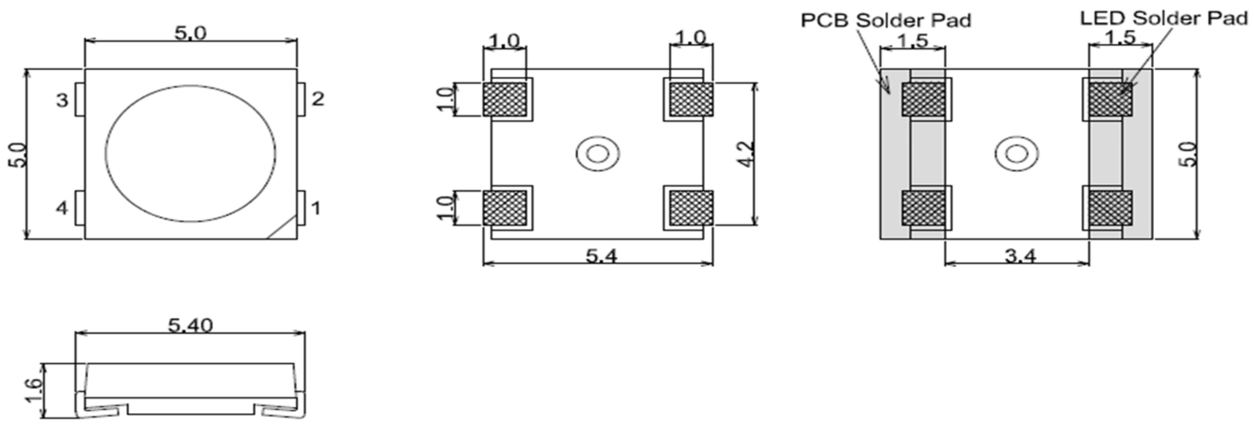
● line data transmission;

● plastic forward strengthening technology, the transmission distance between two points over 10M;

● data transmission frequency up to 800Kbps, when the refresh rate of 30 frames per second, a cascade of not less than 1024;

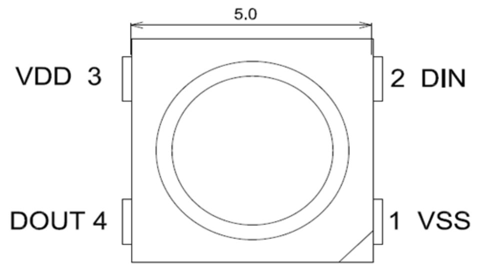
● built-in powerpolarity protection module, powerpolarity will not damage.

Mechanical Product Size (unit mm):



SK6812

Mechanical Size and Pin Map (unit mm):



Pin Function:

Item	Symbol	Pin Name	Function description
1	VSS	Ground	The signal and power supply and grounding
2	DIN	Data Input	control signal input data
3	VDD	Power	power supply pin
4	DOUT	Data Output	control signal output data

The electrical parameters (limit parameters, Ta=25 C, VSS=0V):

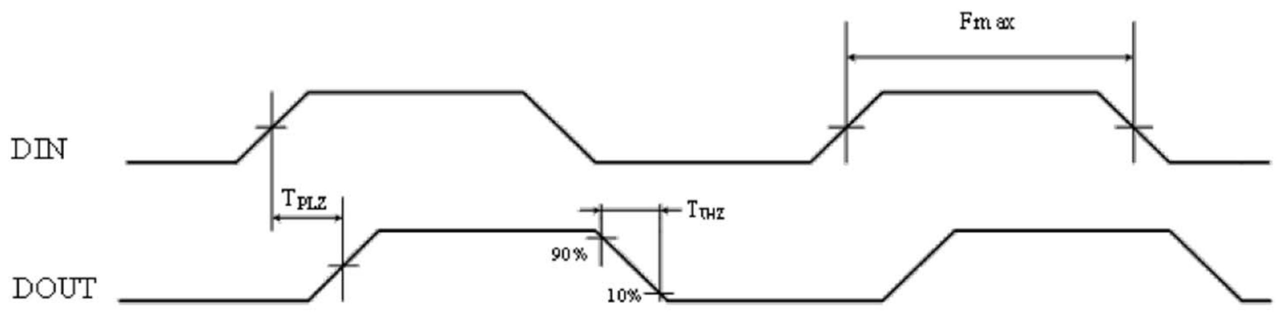
Parameter	Symbol	Range	Unit
Input voltage	V_{IN}	+5	V
Logic input voltage	V_I	-0.5～VDD+5.5	V
Working temperature	Topt	-40~+85	℃
Storage temperature	Tstg	-50~+150	℃
EST pressure	V_{ESD}	4K	V

The electrical parameters (such as no special instructions, TA=-20 ~ +70 ~ 5.5V C, VDD=4.5, VSS=0V):

Parmeter	Symbol	Min	Typical	Max	Unit	Test conditions
The chip supply voltage	VDD	---	5.2		V	---
R/G/B port pressure	VDS,MAX	---	---	26	V	---
DOUT drive capability	IDOH	---	49	---	mA	DOUT conect ground, the maximum drive current
	IDOL	---	-50	---	mA	DOUT conect +, the largest current
The signal input flip threshold	VIH	---	3.4	---		VDD=5.0V
	VIL	---	1.6	---		
The frequency of PWM	FPWM	---	1.2	---	KHZ	---
Static power consumption	IDD	---	1	---	mA	---

The dynamic parameters (Ta=25 C):

Parameter	Symbol	Min	Typical	Max	Unit	Test conditions
The speed of data transmission	fDIN	---	800	---	KHZ	The duty ratio of 67% (data 1)
DOUT transmission delay	T_{PLZ}	---	---	500	ns	DIN→DOUT
	T_{PLZ}	---	---	500	ns	



RGB chip characteristic parameters:

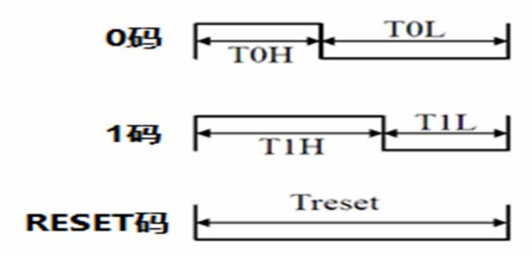
Color	Wavelength(nm)	Luminous intensity(mcd)	Working voltage(v)
Red	620-625	700-1000	2.0-2.2
Green	522.5-525	1500-2200	3.0-3.3
Blue	467.5-470	700-1000	3.0-3.3

The data transmission time (TH+TL=1.25μs±600ns):

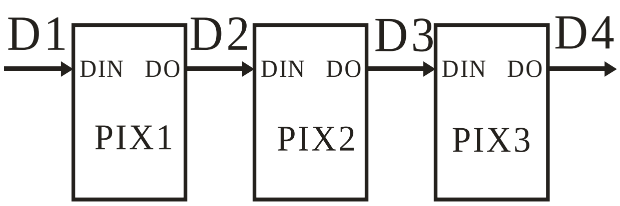
T0H	0 code, high level time	0.3μs	±0.15μs
T1H	1 code, high level time	0.6μs	±0.15μs
T0L	0 code, low level time	0.9μs	±0.15μs
T1L	1 code, low level time	0.6μs	±0.15μs
Trst	Reset code，low level time	80μs	

Timing waveform:

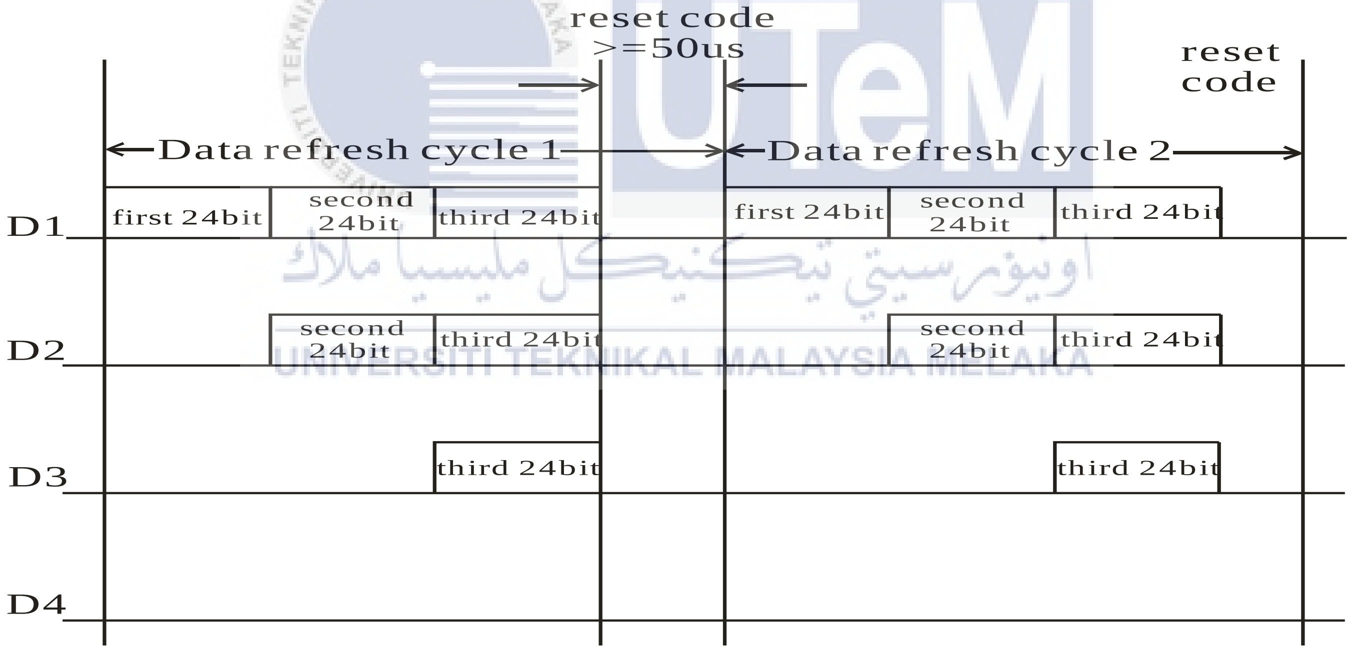
Input code:



Connection mode:



The method of data transmission:



Note: the D1 sends data for MCU, D2, D3, D4 for data forwarding automatic shaping cascade circuit.

The data structure of 24bit:

G7	G6	G5	G4	G3	G2	G1	G0	R7	R6	R5	R4
R3	R2	R1	R0	B7	B6	B5	B4	B3	B2	B1	B0

Note: high starting, in order to send data (G7 - G6 - ....B0)

KA78XX/KA78XXA

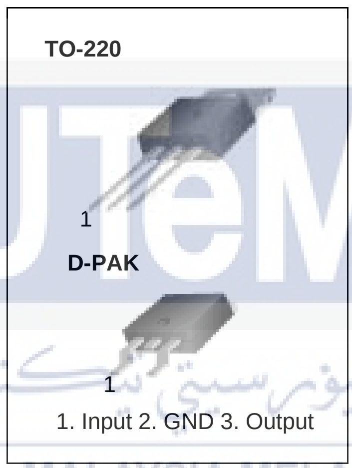
3-Terminal 1A Positive Voltage Regulator

Features

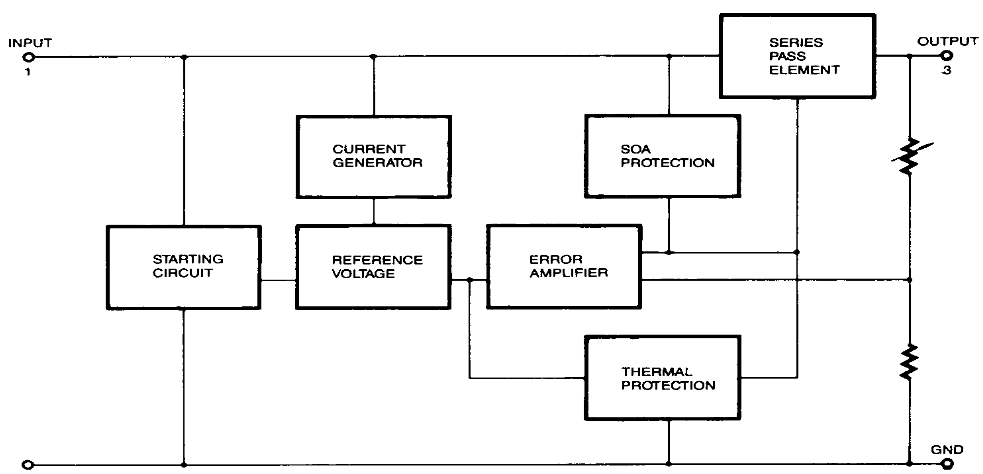
- Output Current up to 1A
- Output Voltages of 5, 6, 8, 9, 10, 12, 15, 18, 24V
- Thermal Overload Protection
- Short Circuit Protection
- Output Transistor Safe Operating Area Protection

Description

The KA78XX/KA78XXA series of three-terminal positive regulator are available in the TO-220/D-PAK package and with several fixed output voltages, making them useful in a wide range of applications. Each type employs internal current limiting, thermal shut down and safe operating area protection, making it essentially indestructible. If adequate heat sinking is provided, they can deliver over 1A output current. Although designed primarily as fixed voltage regulators, these devices can be used with external components to obtain adjustable voltages and currents.



Internal Block Digram



Rev. 1.0.0

Electrical Characteristics (KA7805A)

(Refer to the test circuits. $0^{o}C < T_J < +125\ ^{o}C$, I_O =1A, V_I = 10V, C_I=0.33µF, C_O=0.1µF, unless otherwise specified)

Parameter	Symbol	Conditions	Min.	Typ.	Max.	Unit
Output Voltage	V_O	T_J =+25 ^{o}C	4.9	5	5.1	V
		I_O = 5mA to 1A, $P_O \leq$ 15W V_I = 7.5V to 20V	4.8	5	5.2	
Line Regulation (Note1)	Regline	V_I = 7.5V to 25V I_O = 500mA	-	5	50	mV
		V_I = 8V to 12V	-	3	50	
		T_J =+25 ^{o}C, V_I= 7.3V to 20V	-	5	50	
		T_J =+25 ^{o}C, V_I= 8V to 12V	-	1.5	25	
Load Regulation (Note1)	Regload	T_J =+25 ^{o}C I_O = 5mA to 1.5A	-	9	100	mV
		I_O = 5mA to 1A	-	9	100	
		I_O = 250mA to 750mA	-	4	50	
Quiescent Current	I_Q	T_J =+25 ^{o}C	-	5.0	6.0	mA
Quiescent Current Change	ΔI_Q	I_O = 5mA to 1A	-	-	0.5	mA
		V_I = 8 V to 25V, I_O = 500mA	-	-	0.8	
		V_I = 7.5V to 20V, T_J =+25 ^{o}C	-	-	0.8	
Output Voltage Drift	$\Delta V/\Delta T$	Io = 5mA	-	-0.8	-	mV/ ^{o}C
Output Noise Voltage	V_N	f = 10Hz to 100KHz T_A =+25 ^{o}C	-	10	-	µV/Vo
Ripple Rejection	RR	f = 120Hz, I_O = 500mA V_I = 8V to 18V	-	68	-	dB
Dropout Voltage	V_{Drop}	I_O = 1A, T_J =+25 ^{o}C	-	2	-	V
Output Resistance	r_O	f = 1KHz	-	17	-	mΩ
Short Circuit Current	I_{SC}	V_I= 35V, T_A =+25 ^{o}C	-	250	-	mA
Peak Current	I_{PK}	T_J= +25 ^{o}C	-	2.2	-	A

Note:

1. Load and line regulation are specified at constant junction temperature. Change in V_O due to heating effects must be taken into account separately. Pulse testing with low duty is used.

Typical Perfomance Characteristics

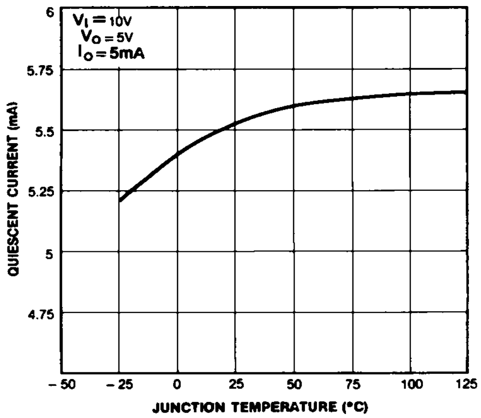


Figure 1. Quiescent Current

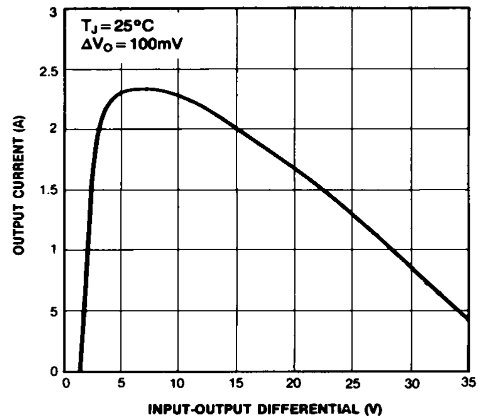


Figure 2. Peak Output Current

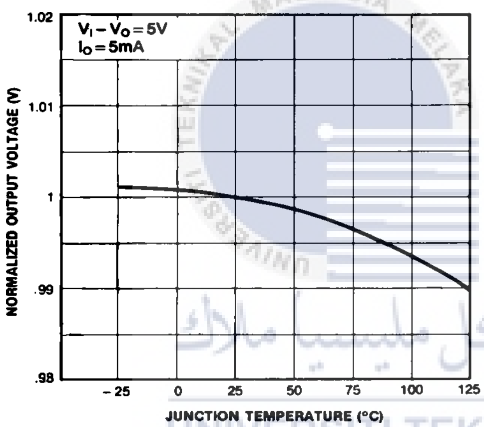


Figure 3. Output Voltage

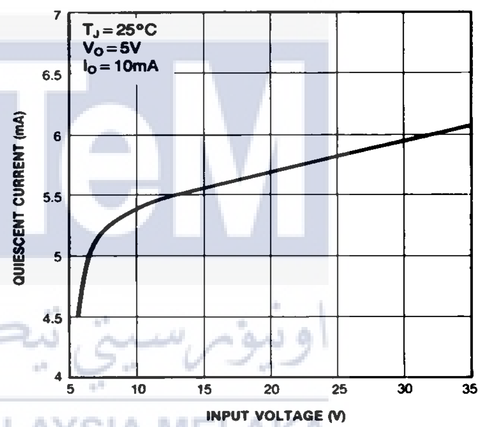


Figure 4. Quiescent Current