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Design, Programming and Implementation of Smart Building Management System Using IoT Technology

A project

Submitted to the Department of Electrical Engineering - University of Technology, in Partial Fulfillment of the Requirements for the Degree of Bachelor of Science in Electronic Engineering

By

Shatha Hani Jasim

Supervised by

Assist. Prof. Sabah Abdul Hassan

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بسم الله الرحمن الرحيم

وقل رب زدني علما

صدق الله العظيم

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<u>Supervisor Certification</u>

I certify that this project entitled (***Design, Programming and Implementation of Smart Building Management System Using IoT Technology***) was prepared under my supervision at Electrical and Electronic Engineering Department, University of Technology as partial fulfillment of the requirements for the degree of B.Sc. in Electronic Engineering.

Assist. Prof. Sabah Abdul Hassan

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Shatha Hani Jasim

Abstract

Smart Building Management Systems are becoming more and more advanced, and the level of integration is being developed progressively from the subsystem level to total building integration and convergence of information systems. Energy used in buildings represents significant part of global energy consumption and humans spend most of the time indoors. Using integrated and smart systems, it is possible to achieve significant reduction in building maintenance costs and energy consumption providing more comfortable living environment at the same time.

This project attempts to meet the minimum requirements for establishing a low-cost and reliable Smart Building Management System.

To answer the questions, we provided two methods of operation, a Building Management Unit that enables the building manager to monitor and control the overall power distribution and consumption of the building, as well as managing fire & gas alerts, and an Apartment Management Unit that provides the occupants a central device to manage their apartments power, fire & gas alerts, temperature and humidity, as well as controlling the electrical appliances such as (TV, refrigerator, HVAC, etc.). An Internet-of-Things enabled mobile application using the Blynk platform has also been design for both units, covering the same functionality and enabling both, the building manager and occupants to manage their units remotely over a WiFi or 3G internet connection.

Our results showed a promising and a reliable implementation of technology with a very fast and accurate response. The touch screen and mobile application proved to be a good solution for this type of projects, as well as the selected hardware components, software and methods of communication.

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Table of Abbreviations

Abbreviation	Meaning
3G	Third Generation of Wireless Mobile Telecommunications Technology
A or Amp	Ampere
AC	Alternative Current
AMU	Apartment Management Unit
API	Application Programming Interface
App	Application
ASCII	American Standard Code for Information Interchange
AVR	Advanced Virtual RISC
BAS	Building Automation System
BMS	Building Management System
BMU	Building Management Unit
cm	Centimeter
CO	Carbon Monoxide
CPU	Central Processing Unit
CT	Current Transformer
DC	Direct Current
EEPROM	Electrically Erasable Programmable Read-Only Memory
GUI	Graphical User Interface
GW	Gateway
HMI	Human-Machine Interface
HVAC	Heating Ventilation Air Conditioning
Hz	Hertz
I/O	Input / Output
IC	Integrated Circuit
ICS	Integrated Communication System
ICSP	In-Circuit Serial Programming
ID	Identification
IDE	Integrated Development Environment

Abbreviation	Meaning
IoT	Internet of Things
IQD	Iraqi Dinar
IR	Infrared
kB	Kilobyte
kW	Kilowatt
kWh	Kilo-Watt Hour
LCD	Liquid Crystal Display
LED	Light Emitting Diode
LPG	Liquefied Petroleum Gas
Lux	Light Intensity Unit
mA	Milli-Ampere
MCU	Microcontroller
MHz	Mega-Hertz
MIT	Massachusetts Institute of Technology
NC	Normally Closed
Nm	Nanometer
NO	Normally Opened
NOR	Not-OR gate
Ohm	Resistance in Ohm
OTP	One-time Programmable
Pf	Power Factor
PIR	Passive Infrared
PPM	Parts Per Million
PWM	Pulse Width Modulation
QBtu	Quadrillion British Thermal Units
RAM	Random Access Memory
RH	Relative Humidity
RISC	Reduced-Instruction-Set Computing
ROM	Read-Only Memory
SBAS	Smart Building Automation System

Abbreviation	Meaning
SBMS	Smart Building Management System
SDK	Software Development Kit
SMS	Short Message Service
SoC	System on a Chip
SRAM	Static Random Access Memory
TFT	Thin Film Transistor
TTL	Transistor-Transistor Logic
TV	Television
Tx/Rx	Transfer/Receive
UART	Universal Asynchronous Receiver-Transmitter
UID	Unique Identifier
USB	Universal Serial Bus
V	Volt
VAC	Volts AC
VCC	Voltage at the Common Collector
VDC	Volts DC
W	Watt
Wi-Fi	Wireless Fidelity

CHAPTER ONE

INTRODUCTION

Chapter One

Introduction

1.1. Introduction:

Smart buildings represent a new and potentially enormous opportunity to save energy. Smart buildings apply technologies to improve the building environment and functionality for occupants/tenants while controlling costs, improving security, comfort and accessibility.

As shown in the Figure 1-1 Summary of Energy Consumption below, buildings in USA today uses 48.7% of the total energy consumption as highest of all energy consumption. This building portion is total of residential and commercial building consumption. So, there are huge opportunities of making this building intelligent to control it better and interact it with end users. [1]

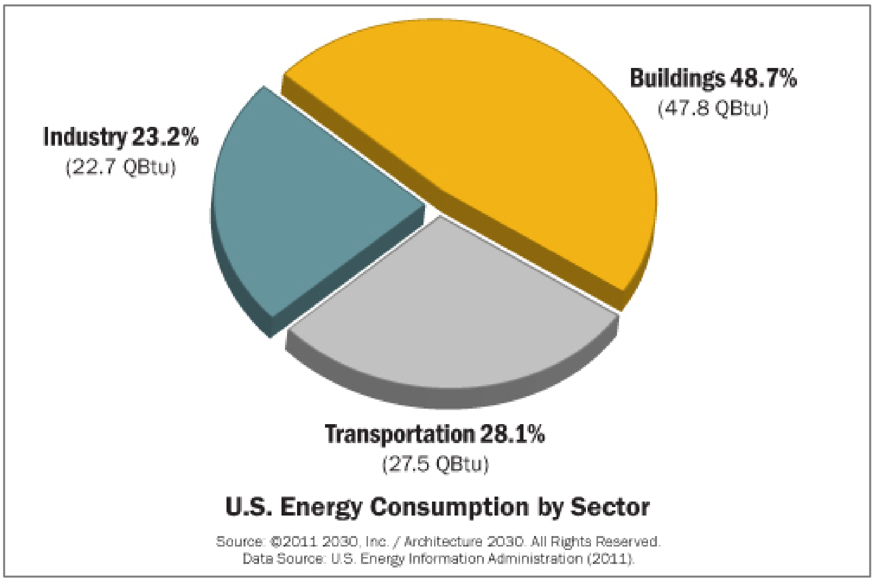


Figure 1-1 Summary of Energy Consumption

Smart (or intelligent) buildings respond to the needs of occupants and society, promoting the well-being of those living and working in them and providing value through increasing staff productivity and reducing operational costs. [2]

This chapter introduces the history of smart buildings evolution, Internet of Things concept, benefits of smart buildings, literature survey, aim of the work and the project organization.

1.2. History and Technological Evolution of Smart Buildings:

The basic controls of a building can be realized in the form of manual switching, time clocks or even temperature switches that provide the on and off signals for enabling pumps, fans or valves etc. Figure 1-2 Intelligent Building Pyramid gives a proper representation for the evolution of intelligent building systems [3].

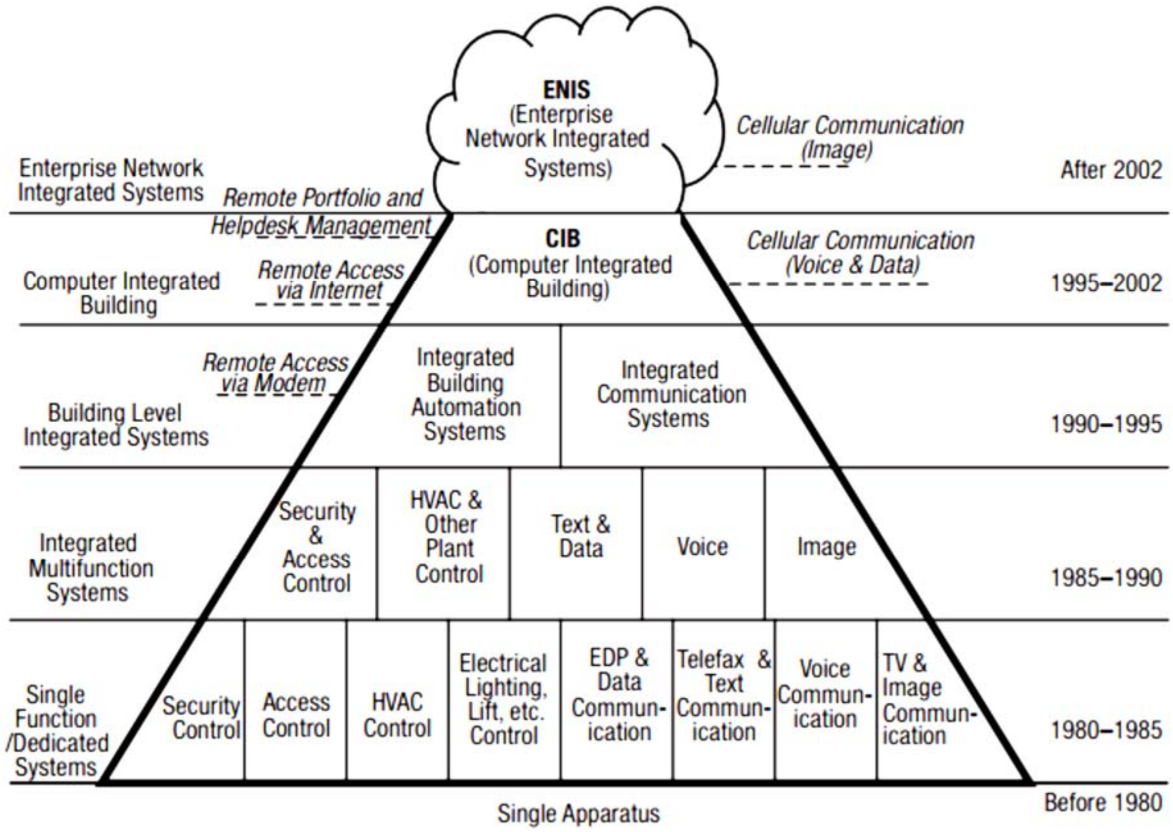


Figure 1-2 Intelligent Building Pyramid

At the beginning, the automation of building systems was achieved at the level of individual equipment, but after 1980, these equipment began to be integrated. So, at the stage of building-level integrated systems, the automations elements and the communication systems were integrated at building-level as Building Automation System (BAS) and Integrated Communication System (ICS) [3]. The system could be accessed remotely via telephone network using a

modem, while the cellular phone for voice and data communication was introduced to the market. At, and after the stage of computer integrated building, due to the intensive use of Internet Protocol and to the increase of communications capacities, convergence networks became available and were used in practice progressively. The integration was at the building level, with remote monitoring and control achieved via the Internet [3].

At the last stage, the Smart Building Management Systems (SBMS) can be integrated and managed at enterprise level or even city level. SBMS of one building are merged with SBMS of other buildings as well as other information systems via the global Internet infrastructure (these systems are not enclosed within buildings); Integration and management at this level become possible due to the applications of advanced IT technologies [3], such as the Internet of Things (IoT) and Web Services.

1.3. The Internet of Things (IoT):

The Internet of things (IoT) is a system of interrelated computing devices, mechanical and digital machines provided with unique identifiers (UIDs) and the ability to transfer data over a network without requiring human-to-human or human-to-computer interaction. [4]

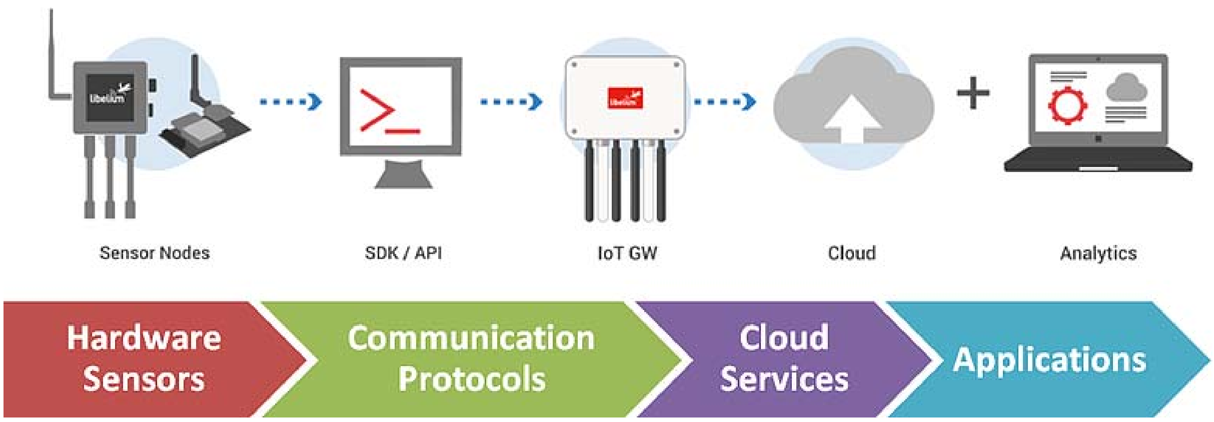


Figure 1-3 IoT Communication Diagram

As of today, the total installed base of Internet of Things (IoT) connected devices are 26.66 billion devices, and it is projected to amount to 75.44 billion worldwide by 2025 [5]. See Figure 1-4 Connected IoT Devices (in billions).

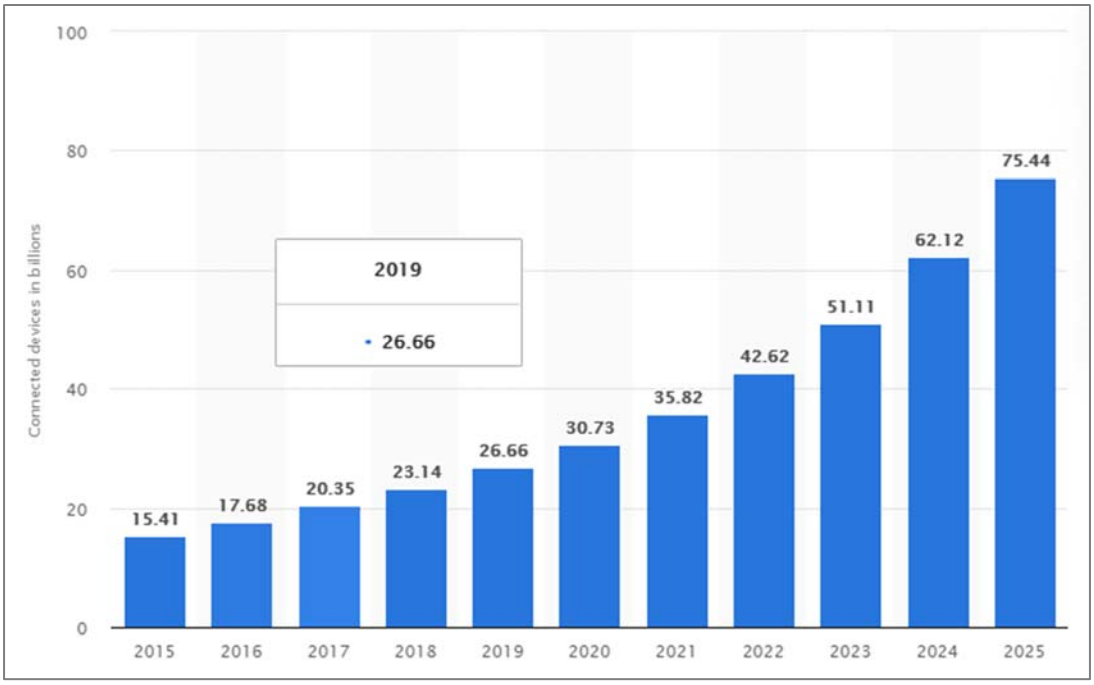


Figure 1-4 Connected IoT Devices (in billions)

Since Building Management Systems (BMS) have long provided centralized but unconnected management for building environments, nowadays IoT played a major role in connecting buildings to the internet, supporting a new level of service provision. The BMS is also extending further into the environments under control with a host of new sensors and actuators deployable within a building to deliver greater levels of detail and control. Occupancy, air quality, humidity, lighting, and many more sensors can all provide a new level of environmental control, lighting and security. [6]

1.4. Benefits of Smart Buildings:

Smart Buildings help the building managers understand how buildings are operating and allow them to control and adjust systems to optimise their performance. They may also be used to monitor and control power distribution, energy consumption, fire and gas detection and security. [7]

Smart buildings introduce a vast range of features and services to both, the owner and the tenants, including the following as a minimum:

- ✓ **Reduce energy consumption:** It could reduce the energy consumption in a building by around 5% -35% with the use of smart technology.

- ✓ **Increase productivity:** Smart buildings make people more productive by continually monitoring the building use and adjust systems to ensure that occupants have the facilities that they need.
- ✓ **Better use of resources:** The data generated by a smart building provides key insights that can be fed into planning and make use of resources more efficient.
- ✓ **Predictive maintenance:** Sensors can detect building performance and activate maintenance procedures before an alert is triggered, such as through counting the operating time of a device or equipment and compare it against the default device age specified by the factory.

1.5. Literature survey:

- **S. Gökceli et al., 2015 [8]:** This paper presents a building automation system based on the Arduino hardware and Android software. The system supports various sensor functions with a very practical and low-cost system configuration. Android blocks that control the Arduino components and sensors are developed with MIT App Inventor 2 software. Additionally, all Arduino components and sensors are put into a unique demonstration model with the purpose of test of the system and the presentation in real-time. With this model, smart building environment is animated and correspondent functions be-come more understandable. Presented system that supports comprehensive functions has also potential for educational usage and teaching activities due to its practical configuration.
- **R. Chasta et al., 2016 [9]:** This paper proposed a system to control the active systems such as lighting including artificial lighting (on/off & dimming control), air conditioners and safety features like fire alarm & gas alarm. In future, the existing idea can be implemented for the whole building, i.e. various rooms or areas and then all of them can be integrated on a common platform for monitoring and control of different equipment.
- **W, Tariq et al., 2012 [10]**: This paper presents a building management system (BMS) that has been designed for Iqra University using AT89C52,

which is the key module in order to perform the controlling and automation. The main area of this BMS focuses on switching and controlling of the power input/output, beside this security and HVAC process has also kept as a main concern in this system.

1.6. The Aim of the Work:

The aim of this project is to provide a Smart Building Management System that is:

- ✓ Easy to install and use
- ✓ Comprehensive and low-cost
- ✓ Able to monitor and control the overall building activities using sensors and actuators, such as power distribution, power measurements, fire & gas detection, security and energy cost estimation.
- ✓ Provide separate control units for each apartment in a building, in order to enable the tenants having full control and monitor over their apartments.

1.7. Project Organization:

Including Chapter One, this project is organized into five chapters:

Chapter Two: Includes the theoretical basis of Smart Building Management System, applications, advantages and system overview.

Chapter Three: This chapter presents the design and implementation of the proposed system.

Chapter Four: This chapter presents the results of the implementations for the practical design.

Chapter Five: This chapter discusses the system findings and provide conclusions and future work suggestions.

CHAPTER TWO

THEORETICAL BACKGROUND AND OVERVIEW OF THE SYSTEM

Chapter Two

Theoretical Background and Overview of the System

2.1. Introduction

Smart buildings are becoming a reality with the integration of Smart Building Management Systems (SBMS), otherwise known as a Smart Building Automation System (SBAS), which is a computer-based control system installed in buildings that controls and monitors the building's mechanical and electrical equipment such as ventilation, lighting, power systems, fire systems, and security systems. [11]. This chapter presents background information and detailed description of the techniques and applications used in the project.

2.2. The System Blocks of a Smart Building Management System

An SBMS consists of several components that facilitates the concept of modern smart monitoring and control system, as shown in the figure below:

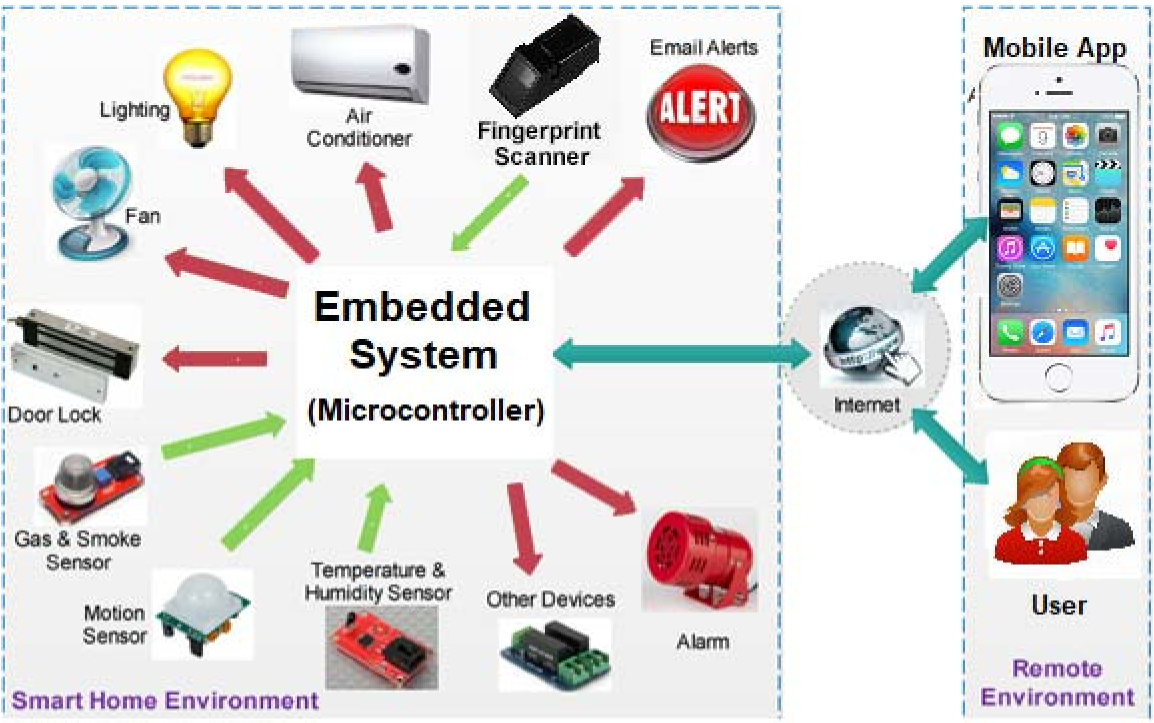


Figure 2-1 The building blocks of a SBMS

The following blocks are the main parts of a typical SBMS:

2.2.1. Controllers (or Microcontrollers)

A microcontroller (MCU for microcontroller unit) is a small computer on a single metal-oxide-semiconductor (MOS) integrated circuit (IC) chip. In modern terminology, it is similar to, but less sophisticated than, a system on a chip (SoC); a SoC may include a microcontroller as one of its components. A microcontroller contains one or more CPUs (processor cores) along with memory and programmable input/output peripherals. Program memory in the form of ferroelectric RAM, NOR flash or OTP ROM is also often included on chip, as well as a small amount of RAM [12]. One type of microcontrollers is AVR [13], which is the most common type used in embedded systems such as Arduino development boards and other products.

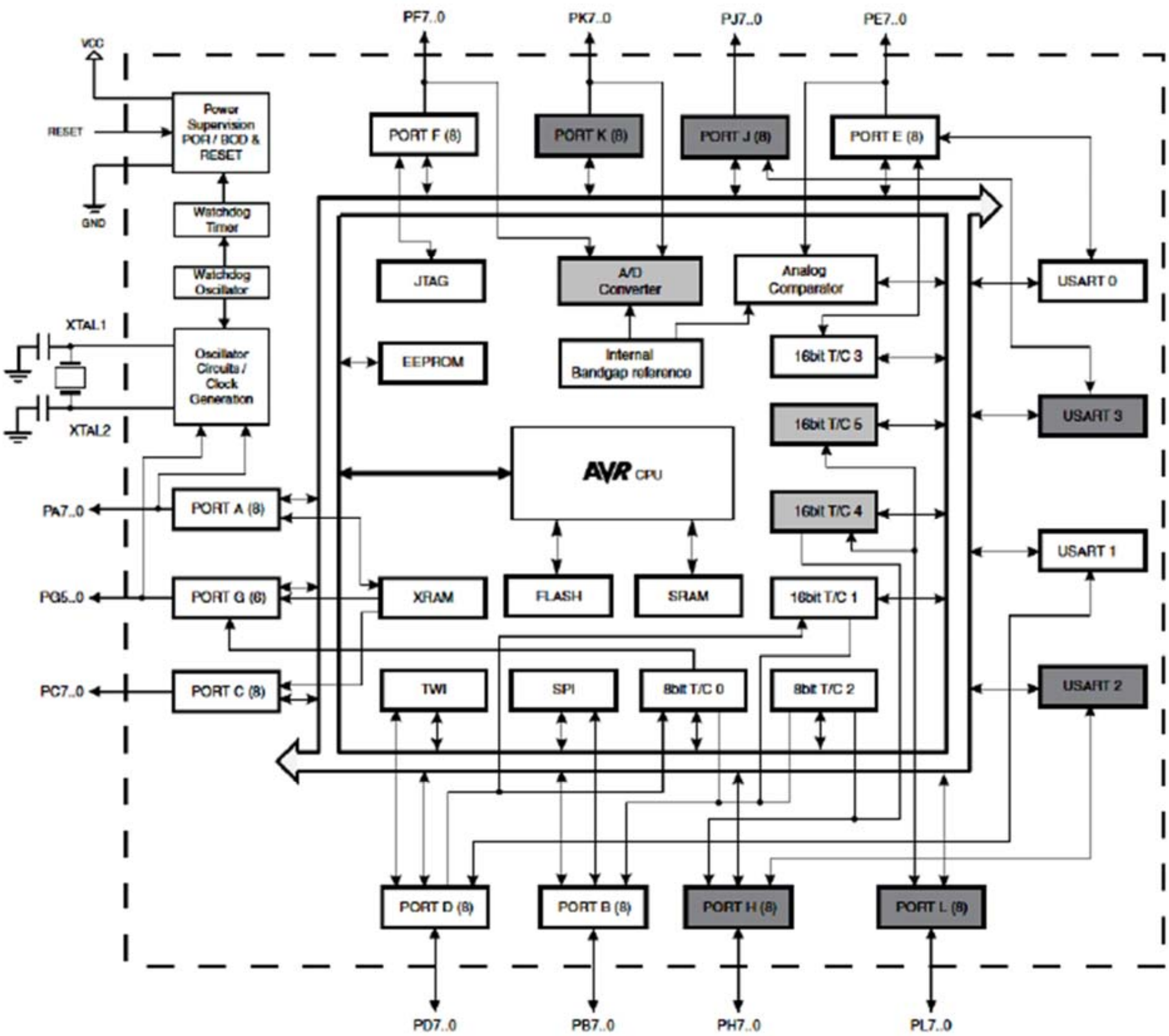


Figure 2-2 AVR Microcontrollers Architecture

Figure 2-3 Different Types of Microcontrollers

Microcontroller Applications:

Microcontrollers are designed for embedded applications, in contrast to the microprocessors used in personal computers or other general purpose applications consisting of various discrete chips. They are used in automatically controlled products and devices, such as automobile engine control systems, implantable medical devices, remote controls, office machines, appliances, power tools, toys and other embedded systems. By reducing the size and cost compared to a design that uses a separate microprocessor, memory, and input/output devices, microcontrollers make it economical to digitally control even more devices and processes. Mixed signal microcontrollers are common, integrating analog components needed to control non-digital electronic systems. In the context of the internet of things, microcontrollers are an economical and popular means of data collection, sensing and actuating the physical world as edge devices [12].

2.2.2. Input and Output Devices

In computing, input/output or I/O is the communication between an information processing system, such as a computer, and the outside world, possibly a human or another information processing system. Inputs are the signals or data received by the system and outputs are the signals or data sent from it.

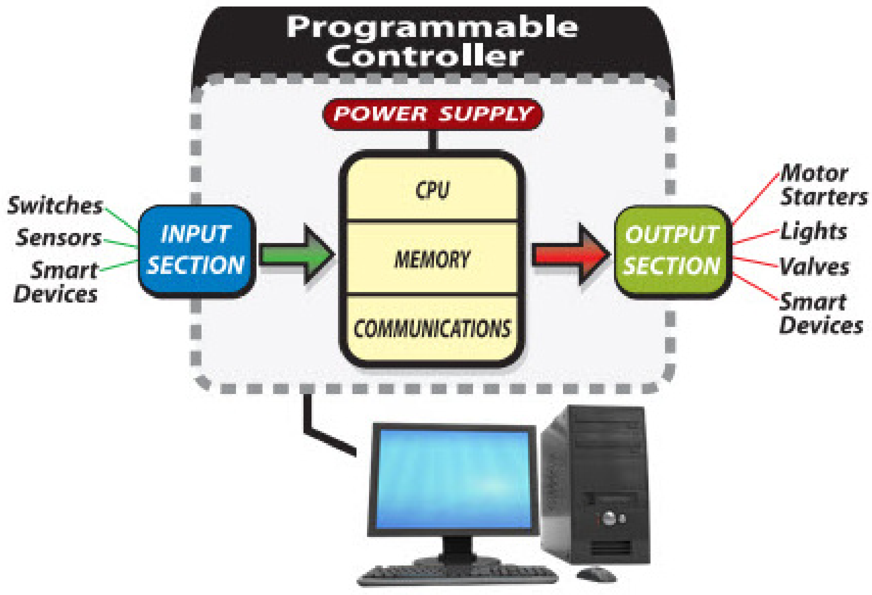


Figure 2-4 Input / Output Block Diagram

Input devices in an SBMS are represented by sensors, where a sensor is a device, module, machine, or subsystem whose purpose is to detect events or changes in its environment and send the information to other electronics, frequently a computer processor [14]. These serve the purpose of measuring parameters such as power consumption, temperature, humidity, lighting levels, room occupancy, etc.

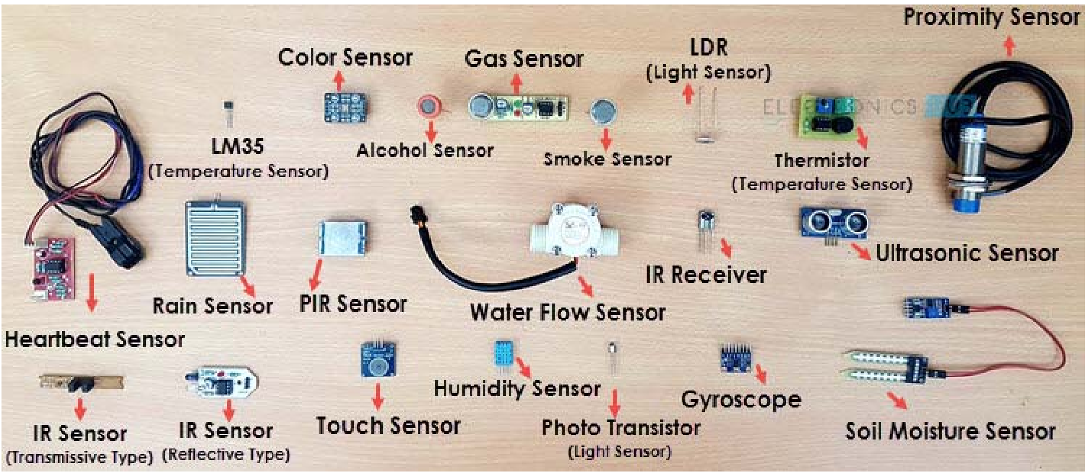


Figure 2-5 Different Types of Sensors

While output devices implement the commands received from the controller. Output devices in electronic systems transform electrical energy into another type of energy, such as light, sound or kinetic energy.

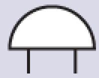
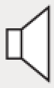
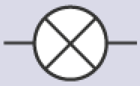
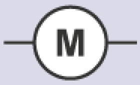
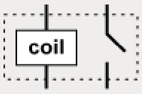
Device	Electrical symbol	Converts electrical energy to
	Buzzer	Sound
	Loudspeaker	Sound
	Lamp	Light
	Light Emitting Diode (LED)	Light
	Motor	Kinetic
	Relay	Kinetic

Figure 2-6 Output Devices Representation

2.2.3. Digital Communication media and supportive protocols.

Digital communication is any exchange of data that transmits the data in a digital form. For example, communications done over the Internet is a form of digital communication [15]. In order to achieve a digital communication between two or many devices, there should be a set of protocol in place in order to organize the data transmission and data security. In the field of internet communications, the Internet Protocol (IP) is the principal communications protocol in the Internet protocol suite for relaying datagrams across network boundaries. Its routing function enables internetworking, and essentially establishes the Internet [16].

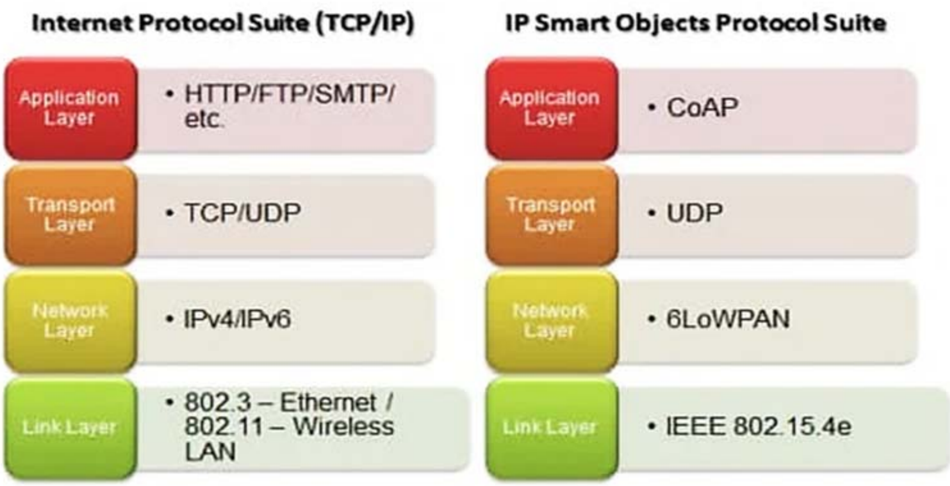


Figure 2-7 Internet and IoT Protocols

2.2.4. Data Analytics

Data analysis is a process of inspecting, cleansing, transforming and modeling data with the goal of discovering useful information, informing conclusions and supporting decision-making [17].

In SBMS, the data comes from power meters, thermometers, pressure sensors, etc. [18]. Then it is analyzed and transformed into human-readable form such as text, numbers, graphs, charts and gauges.

2.2.5. Dashboard

A Digital Dashboard is an electronic interface that aggregates and visualizes data from multiple sources, such as databases, locally hosted files, and web services. Dashboards allow you to monitor your business performance by displaying historical trends, actionable data, and real-time information [19].

Figure 2-8 Digital Dashboards

2.3. Overview of the system

The overall design for the Smart Building Management System is divided into Two main parts:

- Building Management Unit.
- Apartment Management Unit.

The design assumes a typical residence building consisting of four apartments. Only one of these apartments has been programmed as a case study for testing the system's functionality.

2.3.1. Building Management Unit:

It is suggested that the BMU is installed in a Main Control Room and operated either automatically or by a trained person who has the sufficient knowledge to interact with and manage the system through a fixed touch screen.

The BMU should enable the building owner or operator to fully manage (monitor and control) the main building facilities by using touch screen and mobile Wi-Fi application, such as:

- Monitor the gas, smoke and flame sensors for each apartment.
- Monitor the motion sensors in walkways and take action (e.g. turn lights on).
- Monitor the power and energy consumption for the whole building.
- Control the indoor and outdoor lighting.
- Calculate the Cost (Iraqi Dinars) vs. Energy Consumption (kWh) according to the pricing system of the Iraqi Ministry of Electricity.
- Limit the energy consumption for each apartment by setting the value of Amperes (e.g. Apartment-1: 10 amps, Apartment-2: 15 amps) and for both power sources: 1) The National Power Grid. 2) Power Generator.
- Control the power distribution for each apartment (turn on and off).
- The power consumption for each apartment is also displayed on the touch screen. The data is received from the AMUs installed for each apartment.

- The BMU also has the ability to manually control the power feed of the apartments, and set limits for the current consumption.

2.3.2. Apartment Management Unit:

The Apartment Management Unit (AMU) is responsible for monitoring and controlling the apartment electrical power and environmental sensors. Each apartment in the building should have a separate AMU installed in order to enable the tenant having a full control and unique experience.

It is suggested that the AMU is installed at an appropriate location (i.e. near the entrance/main door). It is operated automatically or by the tenant, either through a fixed touch screen, or using the Blynk IoT Mobile Application (Figure 3-11).

The AMU should enable the apartment resident to fully manage (monitor and control) the apartment facilities, such as:

- Use a Fingerprint Scanner for a secure access to the apartment.
- Monitor the temperature, humidity, gas, smoke and flame sensors for each room.
- Monitor the motion sensors in walkways and bathrooms and take action (e.g. turn on the lights).
- Monitor the current and energy consumption for the apartment.
- Control the lights and electrical devices (TV, fridge, HVAC, sockets, etc.).

2.4. Energy Cost Calculation (According to Iraqi Ministry of Electricity)

In this project, a cost calculator was designed and implemented in order to enable the building administrator or the tenant to estimate the expected monthly cost for the given average amount of energy consumption [20]. Refer to Figure 3-9 Energy Cost Calculator Flowchart.

According to the decision of the Iraqi Ministry of Electricity for the year 2018, the following categories have been provided as a standard tariff rating system:

Table 2-1 Energy tariff according to the Iraqi Ministry of Electricity - 2018

Category	Energy (kWh)	Cost (IQD)
1	<= 1500	10
2	> 1500 & <= 3000	35
3	> 3000 & <= 4000	80
4	> 4000	120

The following equations were used to estimate the monthly cost of consumption:

$$P = V \times I \times pF = Watt \dots\dots\dots (1)$$

Where:

P: AC Power (Watt)

V: Voltage Reading (Volt)

I: Current Reading (Ampere)

pF: Power Factor

$$E_T = \frac{P \times t}{1000} = kWh \dots\dots\dots (2)$$

$$E_{Cn} = E_T - \sum_{n=2}^{4} E_{Cn-1} = kWh \dots\dots\dots (3)$$

Where:

E_{Cn}: Energy per category number

E_T: Total Energy (kWh)

P: AC Power (Watt)

t: time (hours)

$$Cost_{Cn} = E_{Cn} \times U_{Cn} = Iraqi\ Dinars \ldots\ldots\ldots.(4)$$

$$Total\ Cost = \sum_{n=1}^{4} Cost_{Cn} = Iraqi\ Dinars \ldots\ldots\ldots.(5)$$

Where:

$Cost_{Cn}$: Cost per category number

E_{Cn}: Energy per category number

U_{Cn}: Unit Cost per category in Iraqi Dinars

Example:

If the daily average current consumption is 10 amperes, the cost estimation will be as follows:

Fixed assumptions:

V = 220 volts, pF = 100% = 1.0

1) Power:

P = V * I * pF = 220 * 10 * 1 / 1000 = **<u>2200 W</u>**

2) Energy:

t = 24 hours * 30 days = 720 hours in a month

E_T = P * t / 1000

E_T = 2200 * 720 /1000 = **<u>1,584 kWh</u>**

3) Cost:

Since the Energy (1,584 kWh) is within Category (2) of the Table 3-1 (kWh > 1500), each category should be calculated separately. The total cost will be the sum of calculated categories:

Category (1):

E_{c1} = 1500 kWh *(according to Table 2-1)*

$Cost_{c1} = E_{c1} \times U_{C1}$

$Cost_{c1}$ = 1,500 * 10 = **15,000 IQD**

Category (2):

$E_{c2} = E_T - E_{C1}$ = 1,584 – 1500 = **84 kWh**

$Cost_{c2} = E_{c2} \times U_{C2}$

$Cost_{c2}$ = 84 * 35 = **2,940 IQD**

Total Cost = $Cost_{c1} + Cost_{c2}$ = 15,000 + 2,940 = **17,940 IQD**

2.5. Hardware Components

2.5.1. Arduino Mega 2560 Microcontroller:

In the subject project, the Arduino Mega 2560 microcontroller board has been used as the core processing unit for the Smart Building Management System. The Arduino Mega 2560 has 54 digital input/output pins (of which 15 can be used as PWM outputs), 16 analog inputs, 4 UARTs (hardware serial ports), a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button. It is powered by 5 VDC through USB port or 6 to 12 VDC through the power jack [21]. There are several models of Arduino boards, such as:

Figure 2-9 Arduino Boards Types

Table 2-2 Microcontrollers Comparison of Different Arduino Boards Types

Description	Nano	Uno	Mega
Microcontroller	Atmega328P	Atmega328P	Atmega2560
Clock Speed	16 MHz	16 MHz	16 MHz
Digital I/O’s	22	14	54
Analog Inputs	8	6	16
PWM’s	6	6	15
Operation Voltages	5 V	5 V	5 V
Recommended Supply Voltage	7-12 V	7-12 V	7-12 V
DC Current per I/O Pin	40 mA	20 mA	20 mA
Flash Memory	32 kB	32 kB	256 kB
SRAM	2 kB	2 kB	8 kB
EEPROM	1 kB	1 kB	4 kB

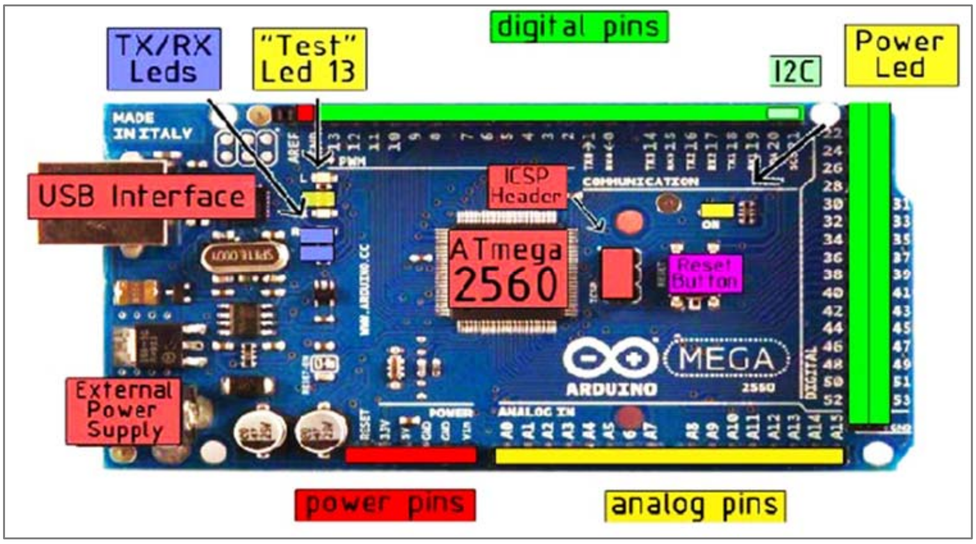


Figure 2-10 Arduino Mega 2560 Board

2.5.2. NodeMCU ESP8266 Microcontroller

The NodeMCU (Node Microcontroller Unit) is an open-source software and hardware development environment built around an inexpensive System-on-a-Chip (SoC) called the ESP8266 providing WiFi connection support which makes it a great IoT gadget. [22]

In this project, it will be used as the Internet of Things Gateway to enable the remote monitoring and control via the Blynk IoT Mobile Application.

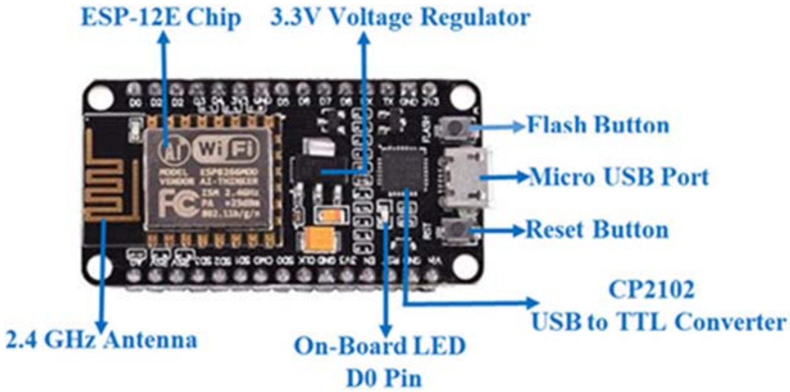


Figure 2-11 NodeMCU ESP8266 (WiFi) Microcontroller

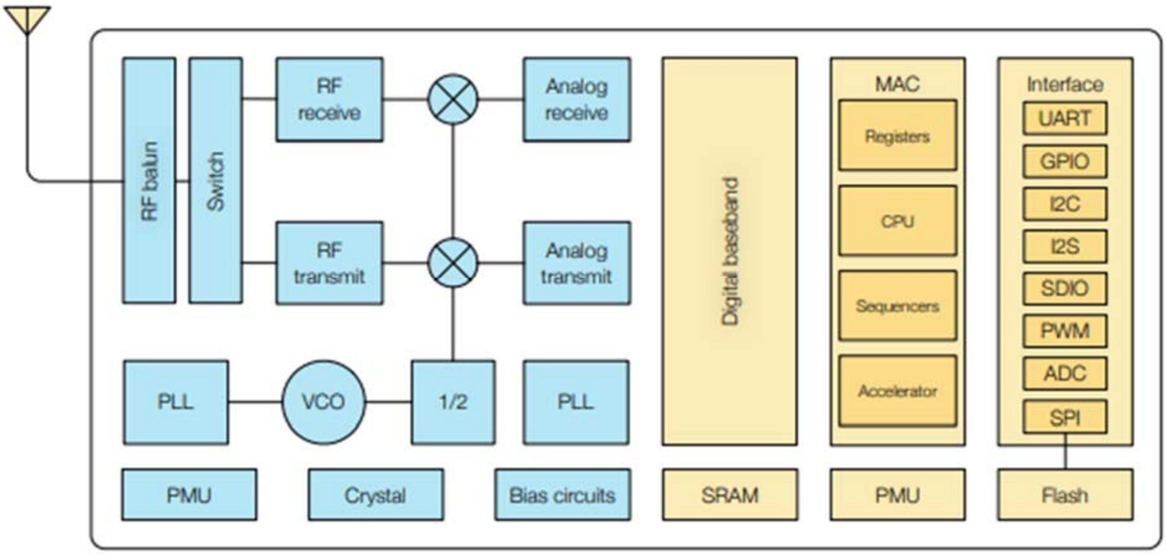


Figure 2-12 NodeMCU ESP8266 Microcontroller Architecture

Applications :

- Home appliances
- Home automation
- Smart plugs and lights
- Industrial wireless control
- Baby monitors
- IP cameras
- Sensor networks
- Wearable electronics
- Wi-Fi location-aware devices
- Security ID tags

2.5.3. Nextion 7.0'' HMI Resistive Touch Screen

Nextion is a Human Machine Interface (HMI) solution combining an onboard processor and memory touch display. Nextion HMI display connects to peripheral MCU via TTL Serial (5V, TX, RX, GND) to provide event notifications that peripheral MCU can act on, the peripheral MCU can easily update progress and status back to Nextion display utilizing simple ASCII text-based instructions. [23]

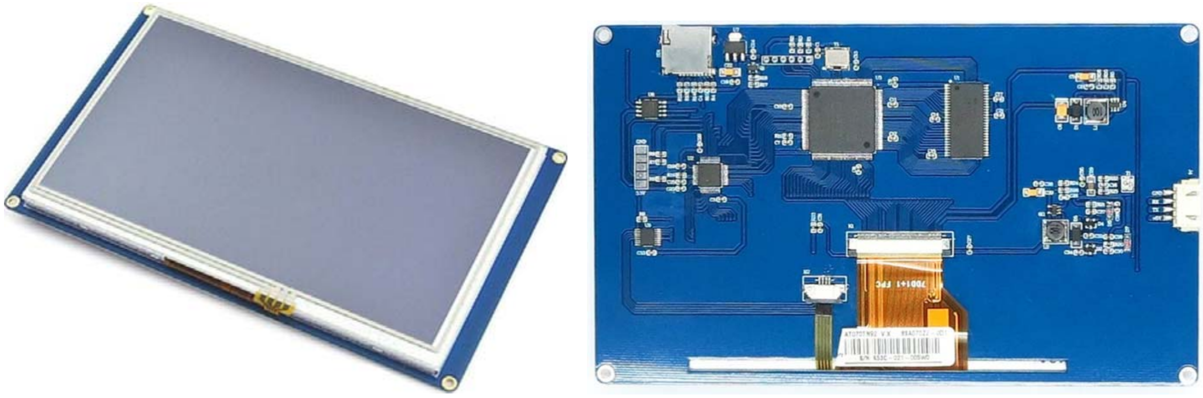


Figure 2-13 Nextion 7.0'' Touch Screen (NX8048P070-011C-Y)

The Nextion touch screen is proposed to be used as the Human-Machine Interface for the Smart Building Management System for its efficiency and professional use.

2.5.4. PZEM-004T Power Multimeter Module

PZEM-004T is an electronic module that functions to measure: Voltage, Current, Power, Frequency, Energy and Power Factors. With the completeness of these functions / features, the PZEM-004T module is ideal for use as a project or experiment for measuring power on an electrical network such as a house or building. [24]

The PZEM-004T is proposed to be used as the Power Measurement devices for all system units due to its high accuracy and efficiency as the results will explain in Chapter-4.

PZEM-004T is capable of measuring up to 100 Amperes of current consumption through the attached Current Transformer (CT).

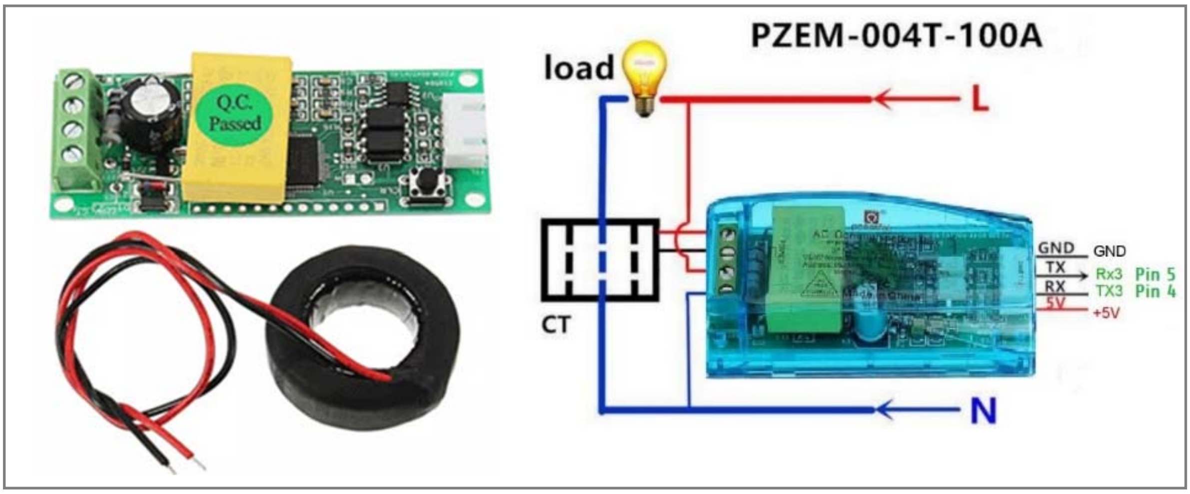


Figure 2-14 PZEM-004T Power Multimeter Module

The power readings result from the combination of integrated algorithms and hardware configuration of the PZEM-004T multimeter module, which is based on the Analog-to-Digital conversion systems:

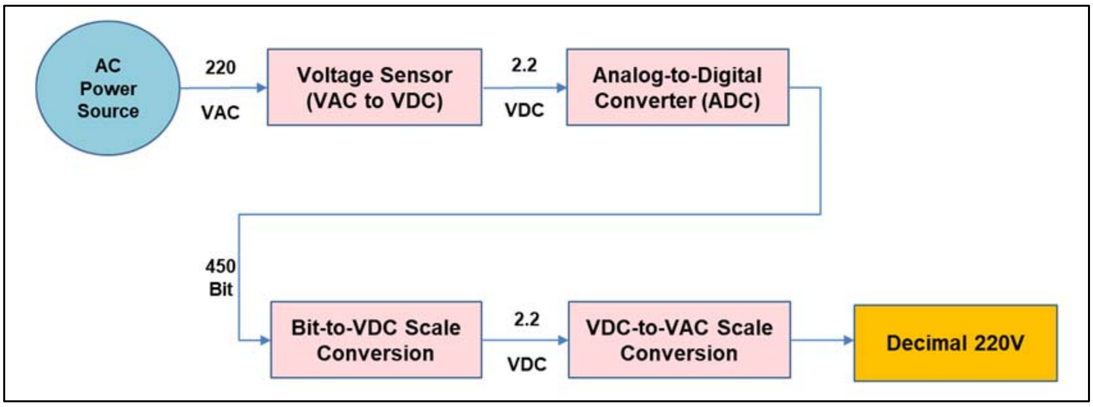


Figure 2-15 Voltage Measurement Methodology

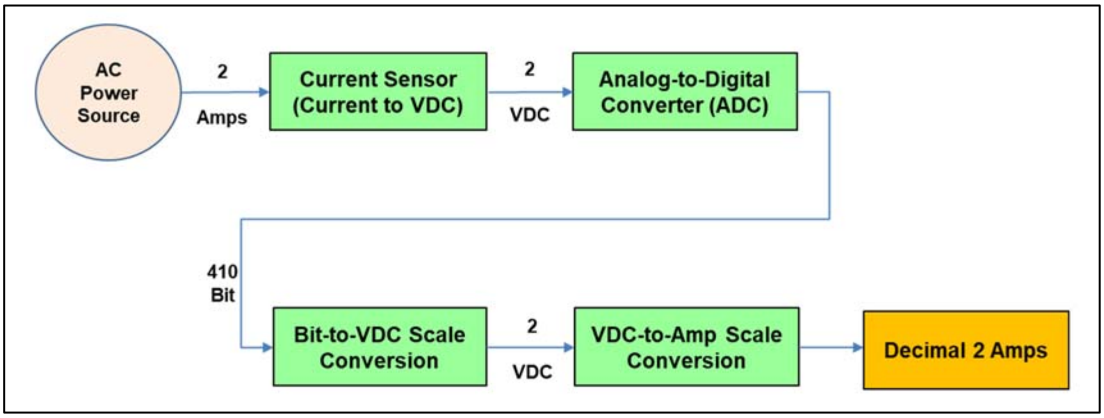


Figure 2-16 Current Measurement Methodology

PZEM-004T Functions:

- Measurement function (voltage, current, power, energy, frequency and pF).
- Power button clear / reset Energy (PZEM-004T V3.0)
- Power-down data storage function (cumulative power down before saving)
- TTL Serial Communication
- Power Measurement: 0 ~ 9999kW
- Voltage Measurement: 80 ~ 260VAC
- Current Measurement: 0 ~ 100A
- Working voltage: 80 ~ 260VAC
- Rated power: 100A / 22000W
- Working Frequency: 45-65Hz
- Measurement accuracy: 1.0

2.5.5. DHT21 Humidity & Temperature Sensor Module:

DHT21 is a high-performance temperature and humidity sensor, providing accurate measurement, low power consumption, long distance data transmission, automatic calibration and long life.

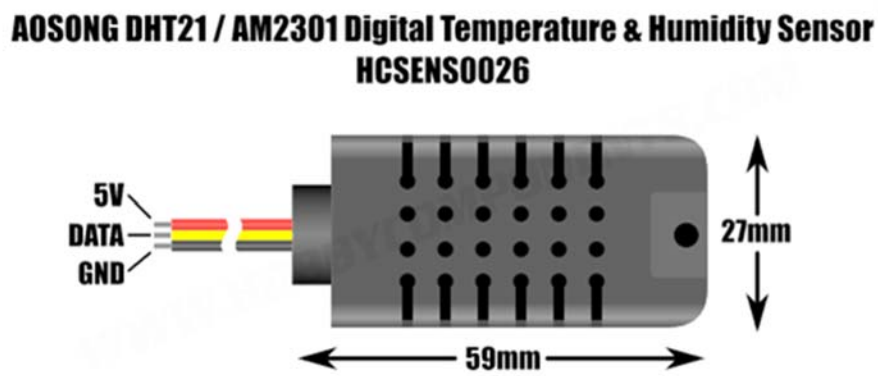


Figure 2-17 DHT22 Sensor

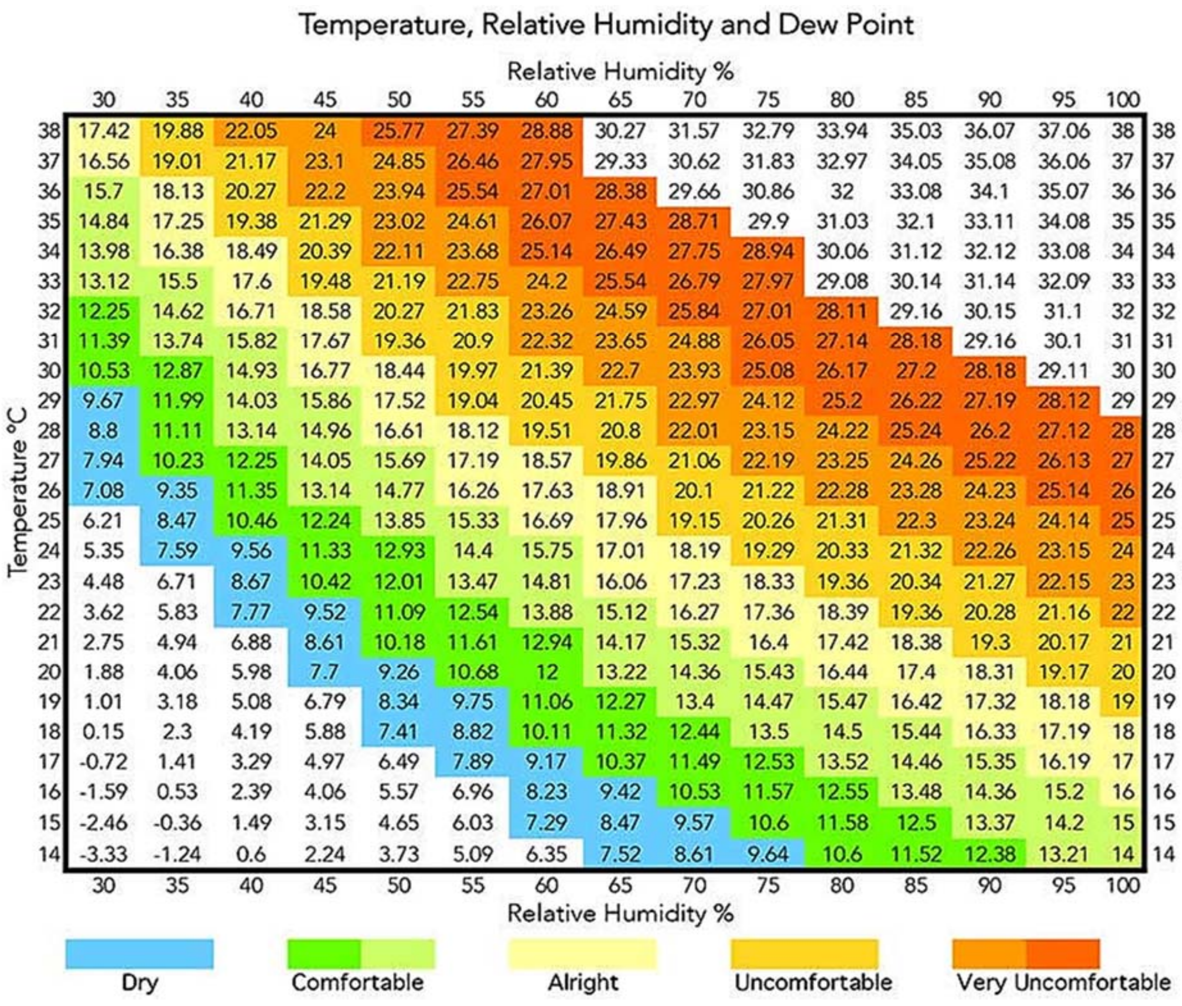
It is perfect for projects that require measurement of temperature and humidity such as greenhouse and portable weather station that provides precise information about the environment. The sensor has small size making it to be easily integrated into the project.

Specifications:

- Humidity sensing range: 0 to 99.9% RH
- Humidity measurement accuracy: ±3% RH
- Temperature measurement range: -40 to 80 °C
- Temperature measurement accuracy: ±0.5 °C
- Supply voltage: 3.3 to 5.2 V

Connection Diagram [25]

- Sensor : Arduino
- Red: 5 V
- Black : GND
- Yellow: Digital I/O pin.



Temperature °C	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100
38	17.42	19.88	22.05	24	25.77	27.39	28.88	30.27	31.57	32.79	33.94	35.03	36.07	37.06	38
37	16.56	19.01	21.17	23.1	24.85	26.46	27.95	29.33	30.62	31.83	32.97	34.05	35.08	36.06	37
36	15.7	18.13	20.27	22.2	23.94	25.54	27.01	28.38	29.66	30.86	32	33.08	34.1	35.07	36
35	14.84	17.25	19.38	21.29	23.02	24.61	26.07	27.43	28.71	29.9	31.03	32.1	33.11	34.08	35
34	13.98	16.38	18.49	20.39	22.11	23.68	25.14	26.49	27.75	28.94	30.06	31.12	32.12	33.08	34
33	13.12	15.5	17.6	19.48	21.19	22.75	24.2	25.54	26.79	27.97	29.08	30.14	31.14	32.09	33
32	12.25	14.62	16.71	18.58	20.27	21.83	23.26	24.59	25.84	27.01	28.11	29.16	30.15	31.1	32
31	11.39	13.74	15.82	17.67	19.36	20.9	22.32	23.65	24.88	26.05	27.14	28.18	29.16	30.1	31
30	10.53	12.87	14.93	16.77	18.44	19.97	21.39	22.7	23.93	25.08	26.17	27.2	28.18	29.11	30
29	9.67	11.99	14.03	15.86	17.52	19.04	20.45	21.75	22.97	24.12	25.2	26.22	27.19	28.12	29
28	8.8	11.11	13.14	14.96	16.61	18.12	19.51	20.8	22.01	23.15	24.22	25.24	26.2	27.12	28
27	7.94	10.23	12.25	14.05	15.69	17.19	18.57	19.86	21.06	22.19	23.25	24.26	25.22	26.13	27
26	7.08	9.35	11.35	13.14	14.77	16.26	17.63	18.91	20.1	21.22	22.28	23.28	24.23	25.14	26
25	6.21	8.47	10.46	12.24	13.85	15.33	16.69	17.96	19.15	20.26	21.31	22.3	23.24	24.14	25
24	5.35	7.59	9.56	11.33	12.93	14.4	15.75	17.01	18.19	19.29	20.33	21.32	22.26	23.15	24
23	4.48	6.71	8.67	10.42	12.01	13.47	14.81	16.06	17.23	18.33	19.36	20.34	21.27	22.15	23
22	3.62	5.83	7.77	9.52	11.09	12.54	13.88	15.12	16.27	17.36	18.39	19.36	20.28	21.16	22
21	2.75	4.94	6.88	8.61	10.18	11.61	12.94	14.17	15.32	16.4	17.42	18.38	19.3	20.17	21
20	1.88	4.06	5.98	7.7	9.26	10.68	12	13.22	14.36	15.43	16.44	17.4	18.31	19.17	20
19	1.01	3.18	5.08	6.79	8.34	9.75	11.06	12.27	13.4	14.47	15.47	16.42	17.32	18.18	19
18	0.15	2.3	4.19	5.88	7.41	8.82	10.11	11.32	12.44	13.5	14.5	15.44	16.33	17.19	18
17	-0.72	1.41	3.29	4.97	6.49	7.89	9.17	10.37	11.49	12.53	13.52	14.46	15.35	16.19	17
16	-1.59	0.53	2.39	4.06	5.57	6.96	8.23	9.42	10.53	11.57	12.55	13.48	14.36	15.2	16
15	-2.46	-0.36	1.49	3.15	4.65	6.03	7.29	8.47	9.57	10.6	11.58	12.5	13.37	14.2	15
14	-3.33	-1.24	0.6	2.24	3.73	5.09	6.35	7.52	8.61	9.64	10.6	11.52	12.38	13.21	14

Figure 2-18 Temperature vs. Relative Humidity Chart

2.5.6. MQ-2 Gas & Smoke Sensor Module:

The MQ-2 gas and smoke sensor can detect or measure smoke and gasses like LPG, Alcohol, Propane, Hydrogen, CO and even methane. The module version of this sensor comes with a Digital Pin which makes this sensor to operate even without a microcontroller and that comes in handy when you are only trying to detect one particular gas. When it comes to measuring the gas in PPM, the analog pin has to be used, the analog pin also TTL driven and works on 5V and hence can be used with most common microcontrollers. [26]

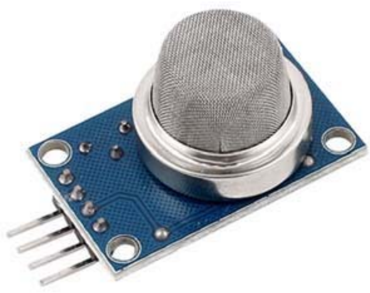


Figure 2-19 MQ-2 Gas & Smoke Sensor

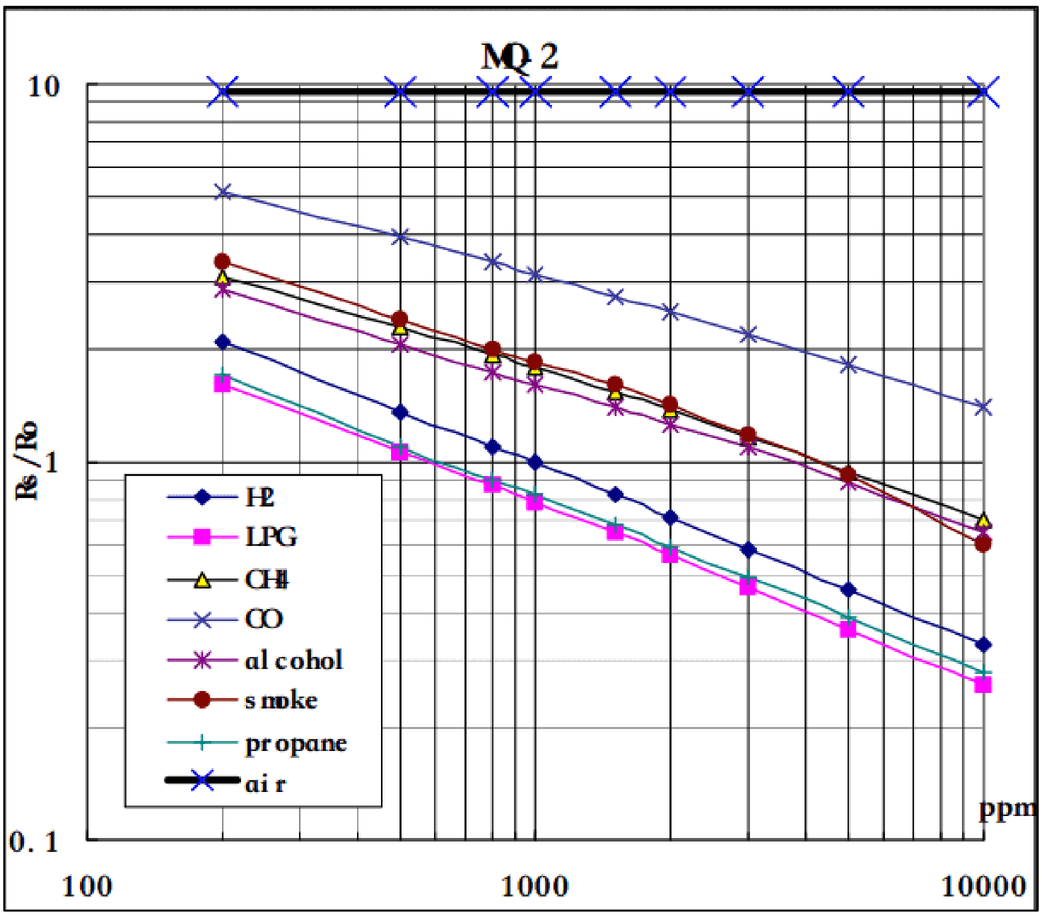


Figure 2-20 MQ-2 Gas Sensor Chart

MQ-2 Technical Details:

- Operating Voltage is +5V
- Can be used to Measure or detect smoke, LPG, Alcohol, Propane, Hydrogen, CO and even methane
- Analog output voltage: 0V to 5V
- Digital Output Voltage: 0V or 5V (TTL Logic)
- Preheat duration 20 seconds
- Can be used as a Digital or analog sensor.
- The Sensitivity of Digital pin can be varied using the potentiometer

2.5.7. PIR Motion Sensor Module:

The PIR Motion sensor module is an automatic control module based on infrared technology. It adopts LHI788 probe, which has high sensitivity, high reliability, low voltage working mode and low power consumption. It can be widely used in various types of automatic induction electrical equipment. [27]

Figure 2-21 PIR Motion Sensor

Technical Details:

Input Voltage	DC 4.5V ~ 20V
Static Current	<50uA
Output Signal	0V / 3V (Output high when motion detected)
Sensing Range	7 meters (120 degrees cone)
Delay time	8s ~ 200s (adjustable)
Operating Temperature	-15℃ ~ +70℃
Dimensions	24mm*32mm*25mm (Height with lens)
Weight	6.6g

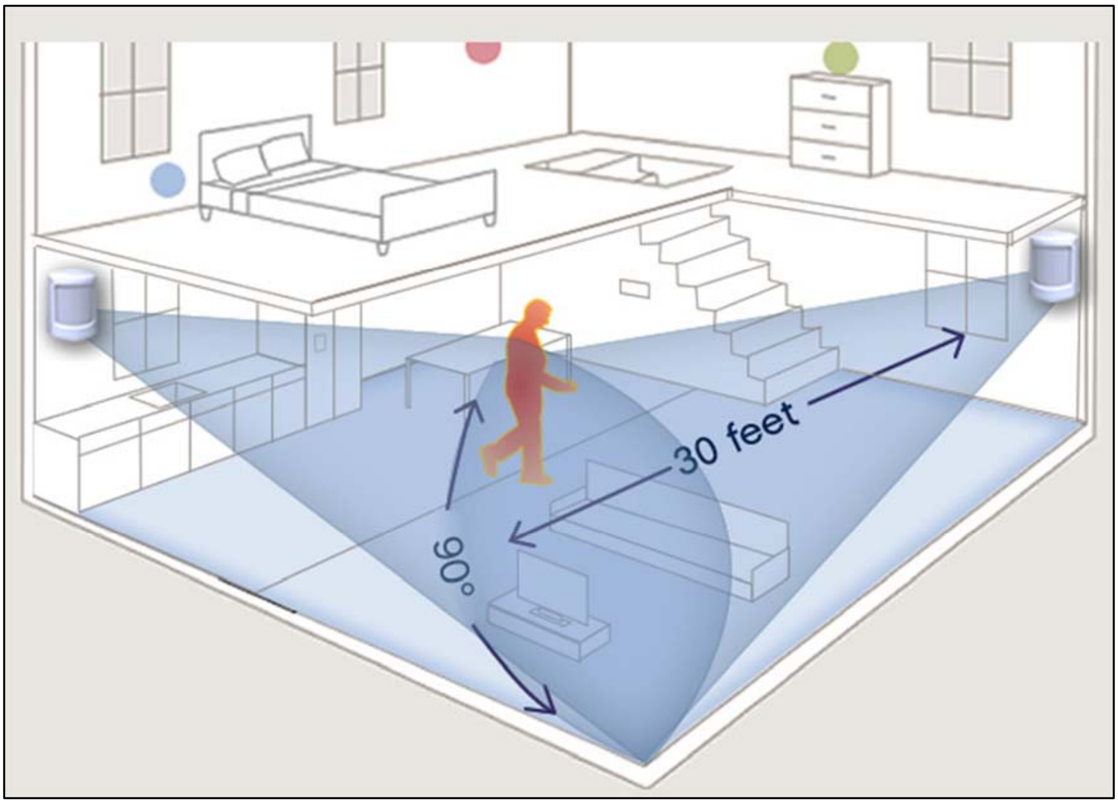


Figure 2-22 Motion Detector Range and Theory

2.5.8. Photocell

A photocell is a resistor that changes resistance depending on the amount of light incident on it. A photocell operates on semiconductor photoconductivity: the energy of photons hitting the semiconductor frees electrons to flow, decreasing the resistance. [28]

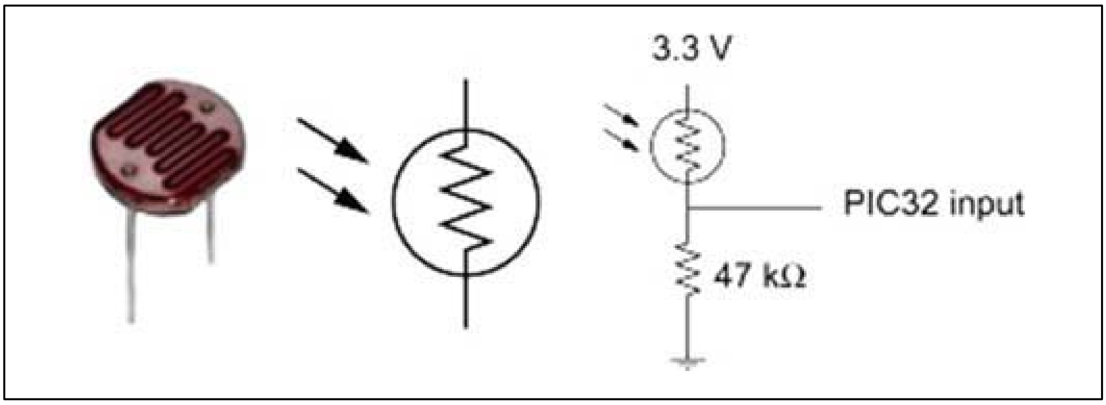


Figure 2-23 Photocell

Figure 2-24 Photocell Resistance vs. Illumination Chart shows the relationship between the resistance (ohm) and the illumination density (lux).

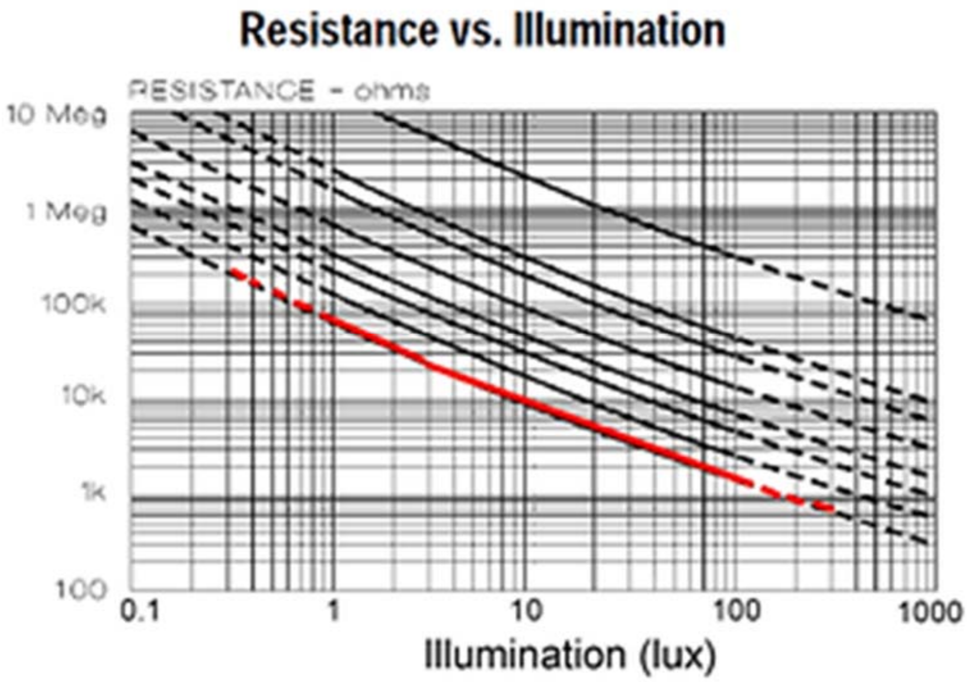


Figure 2-24 Photocell Resistance vs. Illumination Chart

2.5.9. Relay Module

A relay is an electrically operated switch that can be turned on or off, letting the current go through or not, and can be controlled with low voltages, like the 5V provided by the Arduino pins**.** The Arduino-compatible relay modules come in different options: 1, 2, 4, 8 or 16 channels. [29]

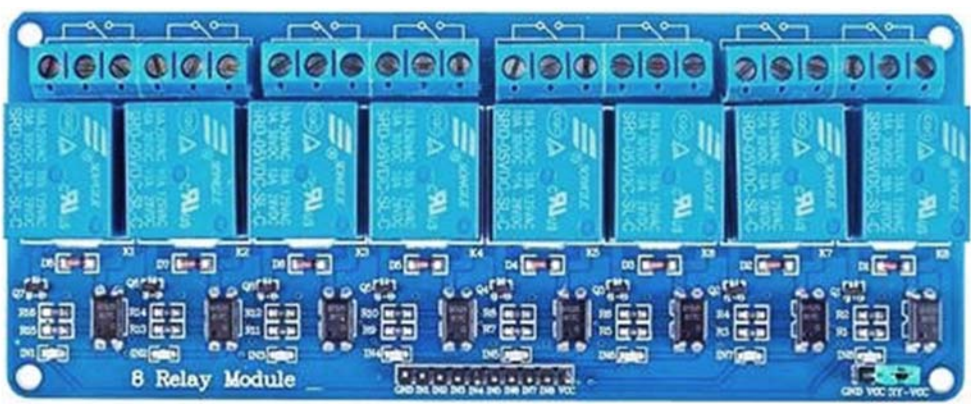


Figure 2-25 Arduino-Compatible 8-Channel Relay Module

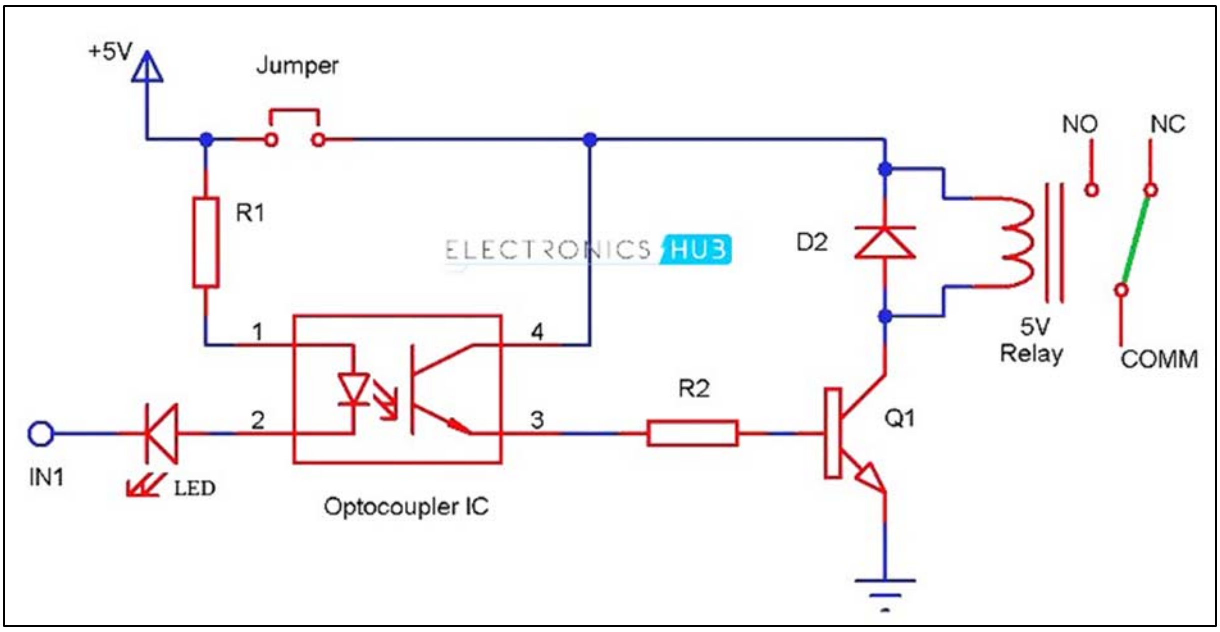


Figure 2-26 Relay Module Circuit Diagram

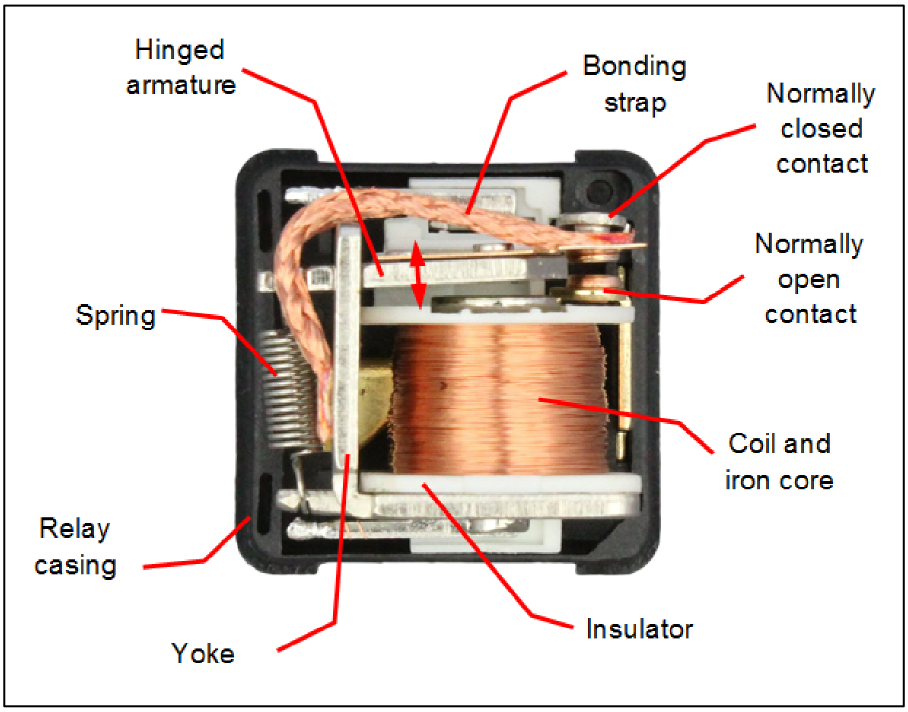


Figure 2-27 Typical NC/NO Relay Structure

Technical Details:

- 5V supply voltage / input signals.
- Jumper to select external or common VCC.
- Straight Headers for control signals.
- Equipped with high-current relay (10A @ 250VAC).
- Size:3.9cm x 5.1cm (1.54inch x 2.01i).

2.5.10. Optical Fingerprint Scanner

Optical fingerprint scanners are the common types of fingerprint scanners that use an LED light to illuminate the finger. The sensor detects and creates the fingerprint image by determining the light and dark areas created by the fingerprint ridges, converts it into digital data and transfer its data to the Microcontroller. Fingerprint scanners are used in different security applications, in this project case; it is used to unlock a door. [30]

Technical Details:

- Supply voltage: DC 3.8-7.0V
- Operating Current: <65mA
- Peak current: 95mA
- Fingerprint image time: 1.0 seconds
- Window area: 14.5*19.4 mm
- Storage capacity: 1000
- False Accept Rate (FAR): <0.001%
- False Reject Rate (FRR): 1.0%
- Search time: 1.0 seconds (1: 500 average)
- PC interface: UART (TTL logic level)
- Lighting: Long light/Flashing.

Figure 2-28 Optical Fingerprint Scanner

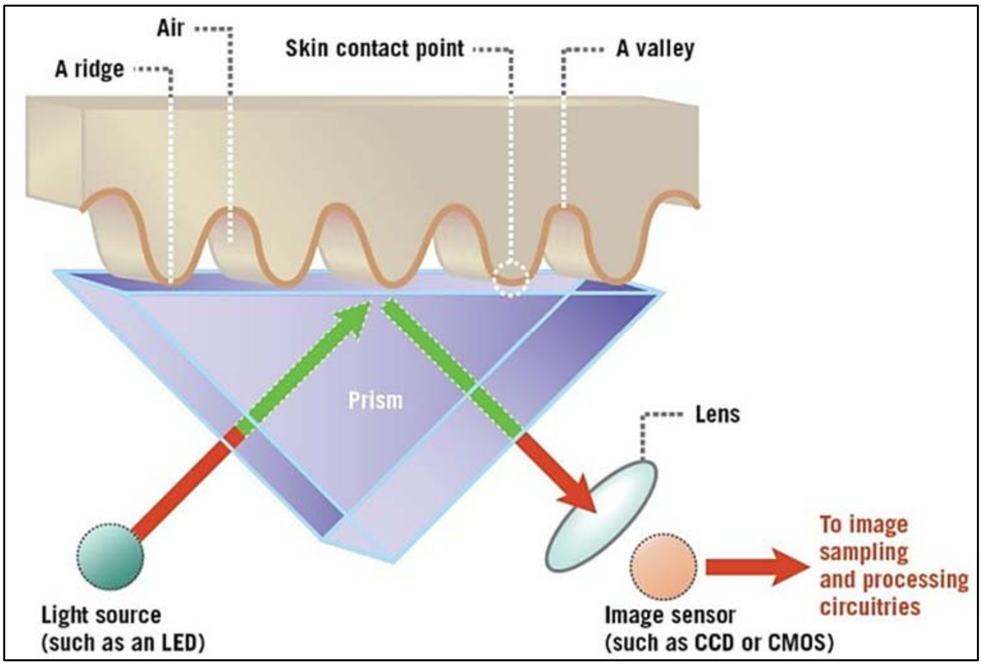


Figure 2-29 Optical Fingerprint Scanner Methodology

2.5.11. Infrared Flame Detector

A flame detector is a sensor designed to detect and respond to the presence of a flame or fire, allowing flame detection. It uses infrared sensor as a flame detector. [31]

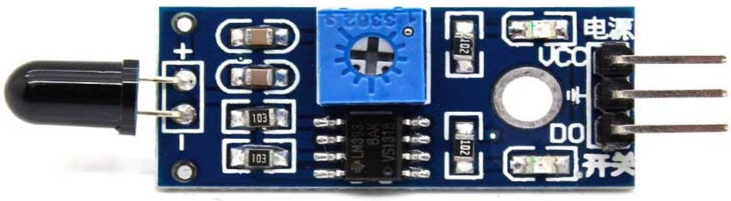


Figure 2-30 Infrared Flame Detector

Overview:

- Sensitive to flame spectrum
- Features wide range voltage comparator LM393
- Adjustable sensitivity
- Signal output indicator

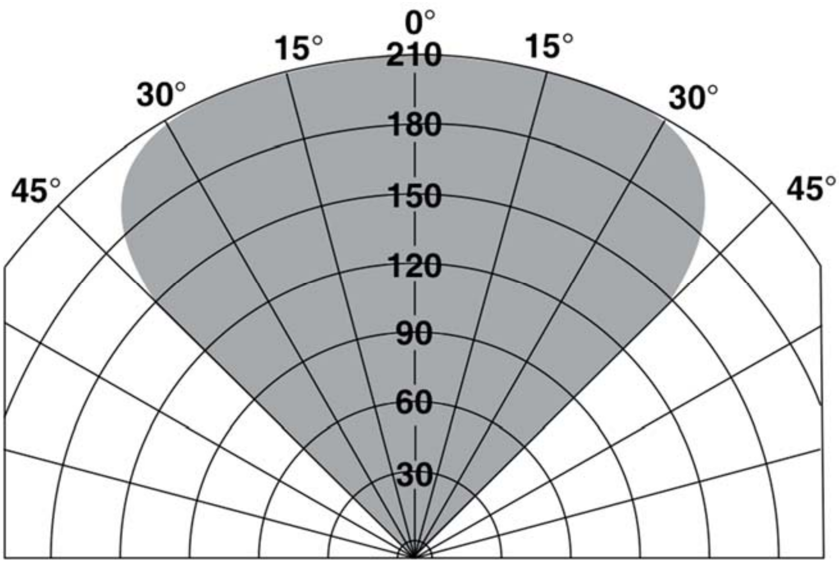


Figure 2-31 Flame Sensor Fire Detection Range Cone

Specifications:

- Spectrum range: 760nm ~ 1100nm
- Detection angle: 0 - 60 degree
- Power: 3.3V ~ 5.3V
- Operating temperature: -25℃ ~ 85℃

2.6. Software

2.6.1. Arduino IDE:

The Arduino integrated development environment (IDE) is a cross-platform application (for Windows, macOS, Linux) that is written in the programming language Java. It includes a code editor with features such as text cutting and pasting, searching and replacing text, automatic indenting, brace matching, and syntax highlighting, and provides simple one-click mechanisms to compile and upload programs to an Arduino board. It also contains a message area, a text console, a toolbar with buttons for common functions and a hierarchy of operation menus. [32]

Figure 2-32 Arduino IDE Interface below shows a sample code written in Arduino IDE to run the Built-in LED of the Arduino Mega 2560 board:

Figure 2-32 Arduino IDE Interface

2.6.2. NEXTION Editor

NEXTION Editor is a development software used for visual building of graphic interface for embedded GUI-intensive devices with various types of TFT displays and Touch Panels. Using this tool, users can start creating TFT based devices in a faster and easier way. [33]

Using the NEXTION Editor software, users can quickly develop the HMI GUI by drag-and-drop components (graphics, text, button, slider etc.) and ASCII text-based instructions for coding how components interact at display side.

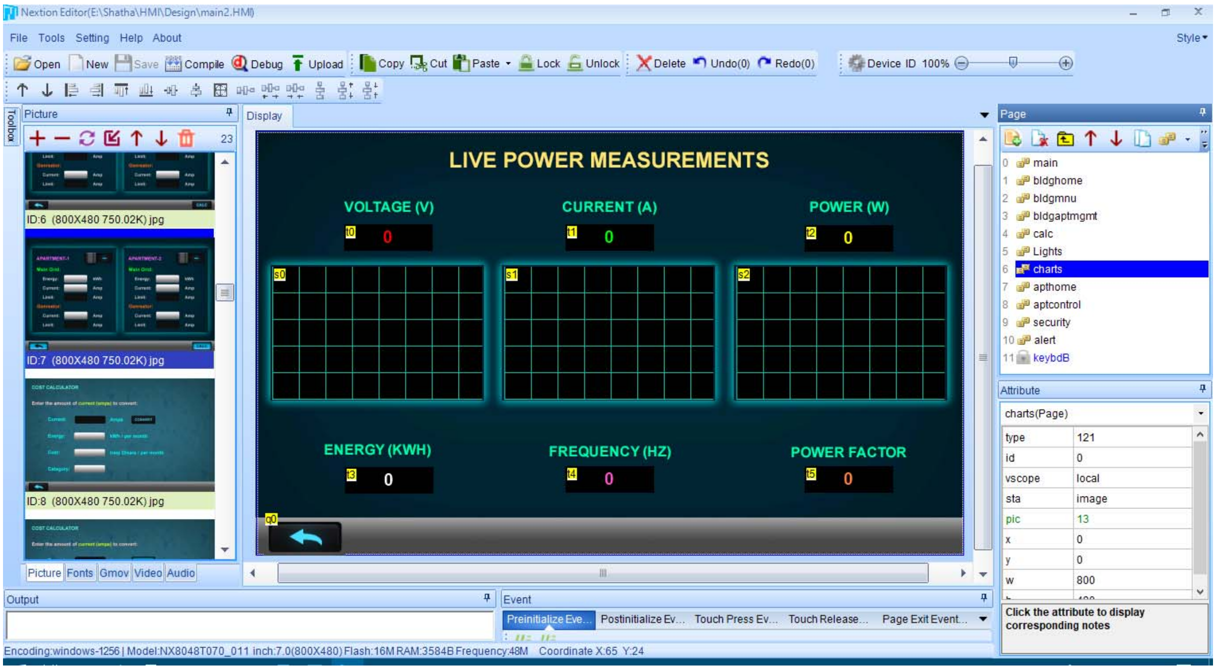


Figure 2-33 NEXTION Editor Software

2.6.3. Blynk IoT Platform

Blynk is an Internet-of-Things platform designed to make development and implementation of smart IoT devices quick and easy. It can be used to read, store, and visualize sensor data and control hardware remotely.

The mobile app developed by Blynk works as a control panel for visualizing and controlling the hardware. It is available for both Android and iOS. The app offers a very productive interface and various different widgets for different purposes. Blynk works on a currency of its own called energy. New users get 2000

amount of Blynk energy with a free Blynk account and this energy is used to buy and deploy widgets in the projects [34].

Blynk can easily be integrated with NodeMCU ESP8266 WiFi Microcontroller using the Blynk Arduino Library and an active WiFi internet connection.

Figure 2-34 Blynk IoT Mobile Application

CHAPTER THREE

SYSTEM DESIGN AND PRACTICAL IMPLEMENTATION

Chapter Three

System Design and Practical Implementation

3.1. Introduction

In this chapter, the overall system design and practical implementation will be categorized and explained in details.

The following activities were performed accordingly, resulting in a comprehensive and functional Smart Building Management System:

- Design of electronic and electrical circuits and wiring diagrams.
- Hardware selection and assembly.
- Writing the sequence of operation and the control algorithms.
- Software design and programming.
- Design of a customized Graphical User Interface for a fixed Touch Screen.
- Implementation of IoT Mobile Application for monitoring and controlling the system remotely using the Blynk Internet of Things platform.

3.2. Electronic Components and Circuit Diagrams

3.2.1. Building Management Unit

The following components have been used to build the end-user device for the Building Management Unit, and as shown in Figure 3-1 Electrical Diagram - Building Management Unit:

1. Arduino Mega 2560
2. NodeMCU ESP8266 WiFi Microcontroller (optional for mobile app).
3. Nextion 7” Resistive Touch Screen
4. PZEM-004T Multifunction Serial Power Meter Module
5. Ambient Light Sensor (Photocell)
6. 8-Channels Relay Module
7. Alarm Buzzer
8. Different types of wires, and a plastic box

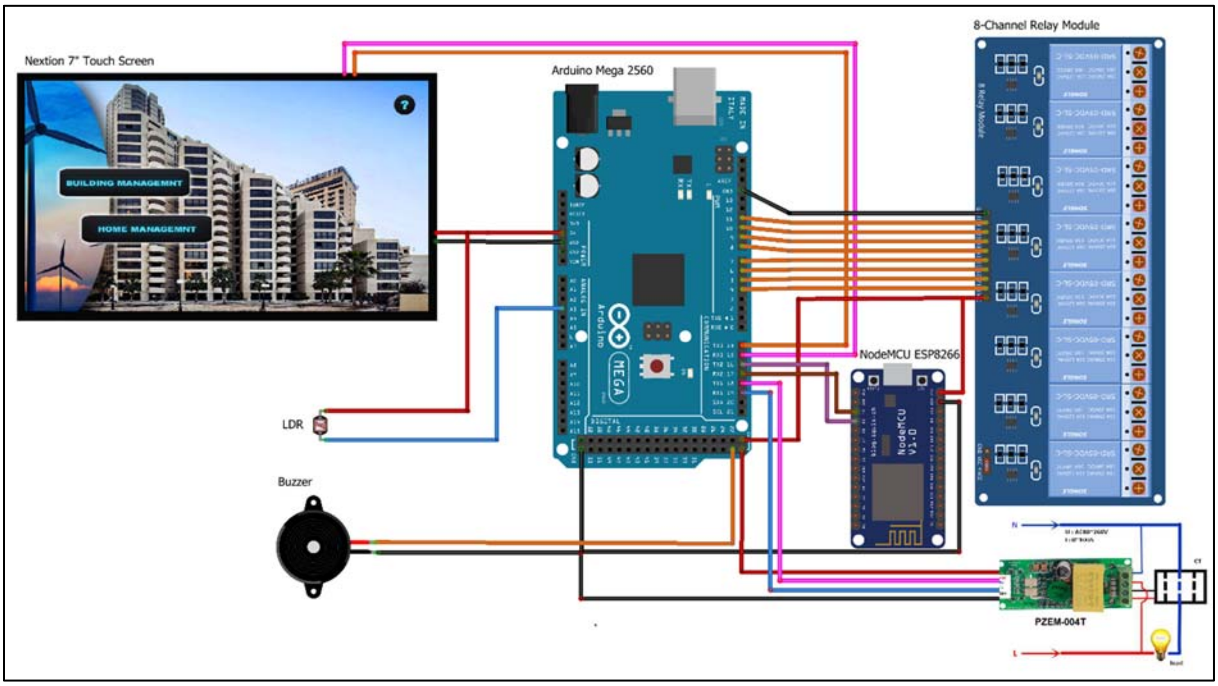


Figure 3-1 Electrical Diagram - Building Management Unit

3.2.2. Apartment Management Unit

The following components have been used to build the end-user device for the Apartment Management Unit, and as shown in Figure 3-2 Electrical Diagram - Apartment Management Unit:

1. Arduino Mega 2560
2. NodeMCU ESP8266 WiFi Microcontroller
3. Nextion 7" Resistive Touch Screen
4. PZEM-004T Multifunction Serial Power Meter Module
5. MQ-134 Gas & Smoke Sensor Module
6. Infrared Flame Detector Module
7. PIR Motion Detector
8. Optical Fingerprint Scanner
9. DHT21 Humidity and Temperature Sensor
10. 8-Channels Relay Module
11. Alarm Buzzer
12. Different types of wires, and a plastic box.

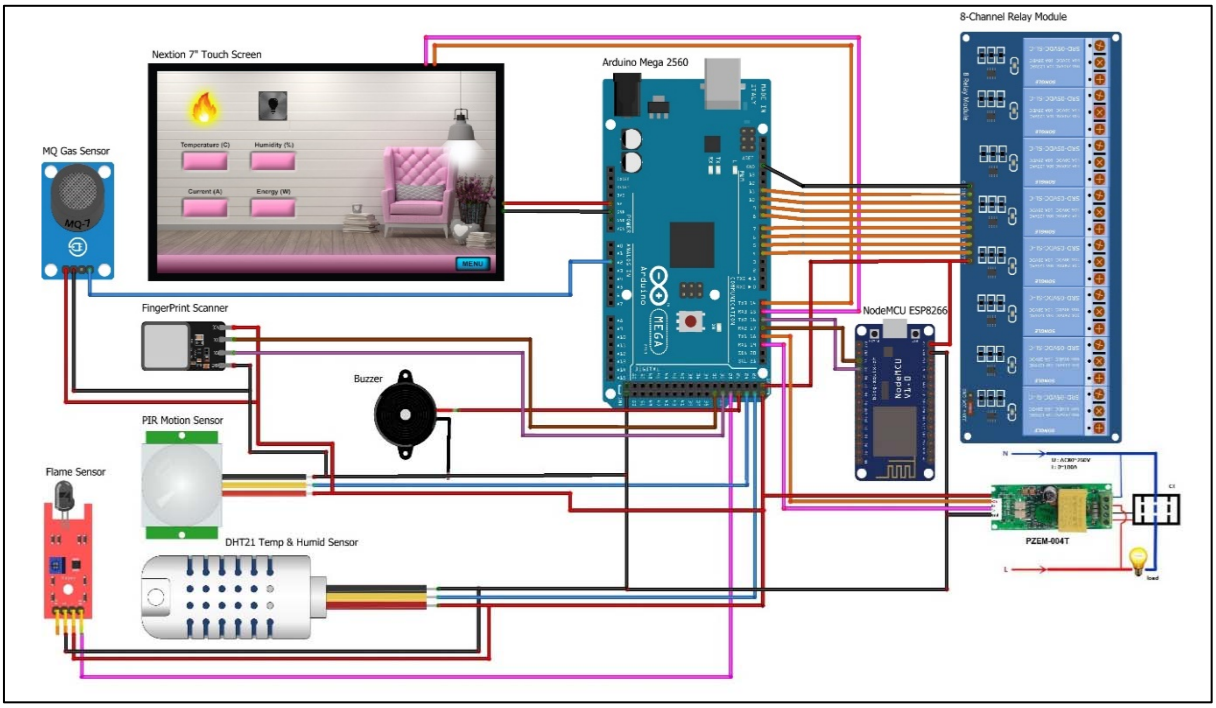


Figure 3-2 Electrical Diagram - Apartment Management Unit

3.3. Methodology

3.3.1. Overview

Both, the Building Management Unit and the Apartment Management Unit are based on Arduino Mega 2560 microcontroller as the main processing unit, associated with a 7 inches touch screen, number of sensors that measure the power consumption and sense the surrounding environment changes such as light, fire, gas, motion, security, etc., as well as actuators that respond to a specific event (i.e. relays and buzzers). All units contain an Integrated Energy Smart Meter that monitors the power measurements and calculates the energy consumption:

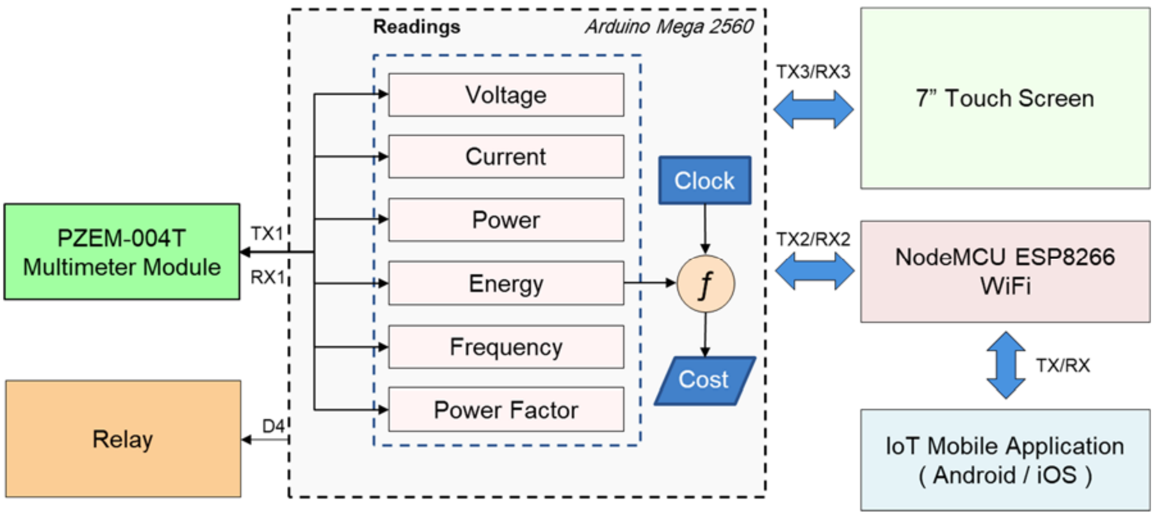


Figure 3-3 Integrated Smart Energy Meter Functional Diagram

3.3.2. Building Management Unit Methodology

The following functional diagram illustrates the basic concept of hardware communication and signal flow directions for the BMU:

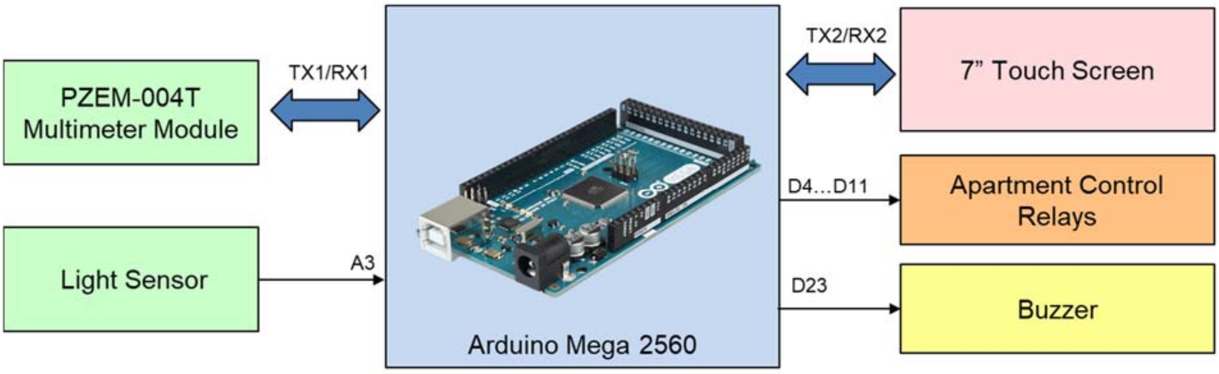


Figure 3-4 Building Management Unit - Functional Diagram

3.3.2.1. Power Measurement

The BMU's microcontroller receives the overall building power measurement data from the PZEM-004T multimeter sensor module and display the results on the 7" Touch Screen, and updates the readings each one second.

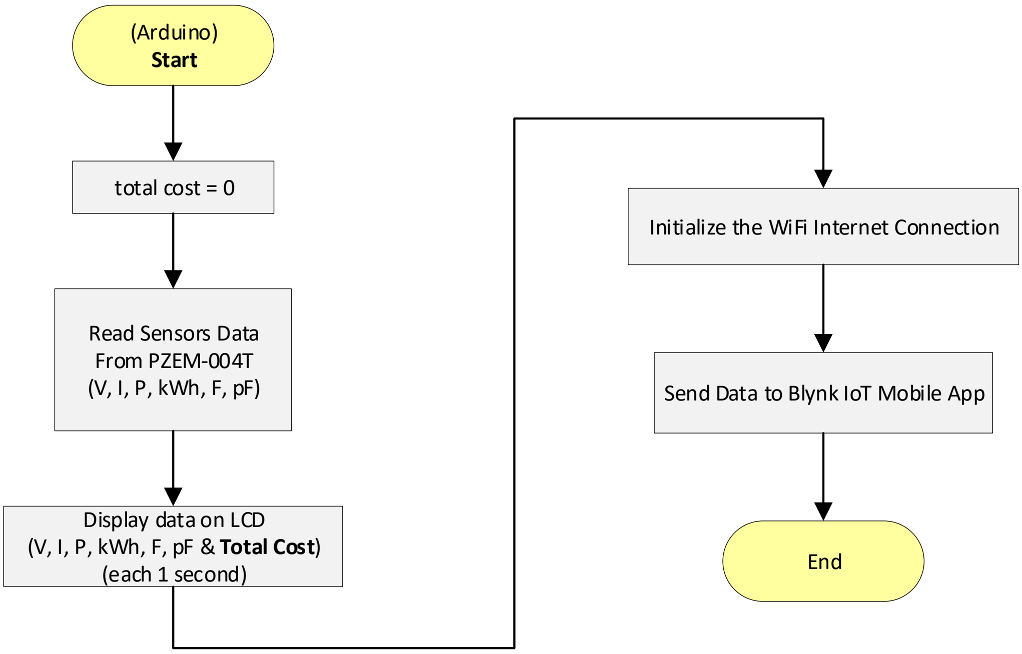


Figure 3-5 Power Measurement Flowchart

3.3.2.2. Overvoltage & Undervoltage Protection

In case of overvoltage (above 240V) or undervoltage (under 180V), the microcontroller will automatically turn off the main building power relay, then turns off the power contactor in the Control Room of the building. The

microcontroller then waits for the voltage to restore its normal state, and turn on the power again.

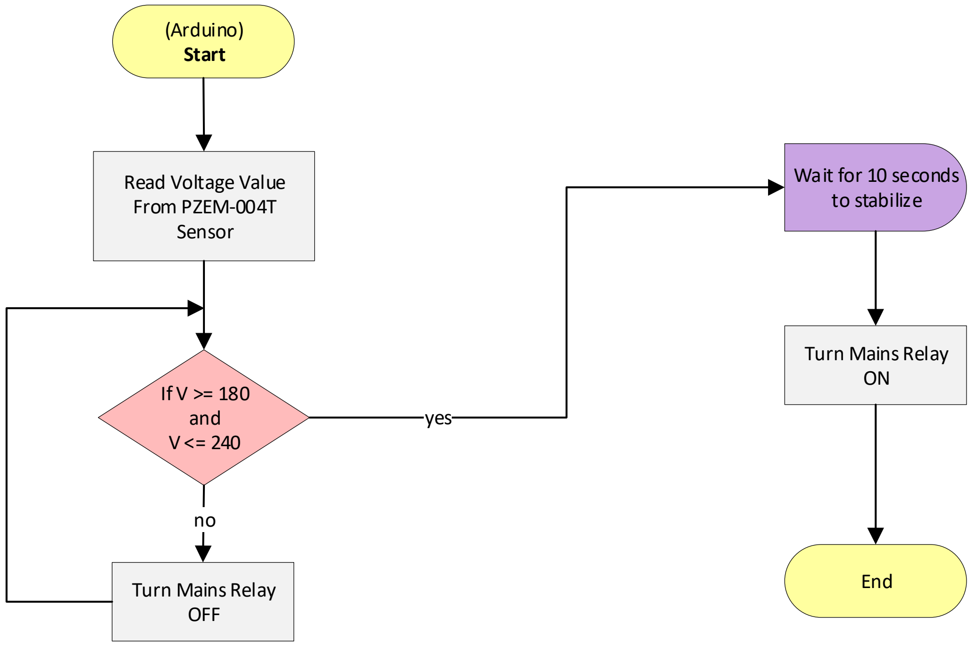


Figure 3-6 Overvoltage & Undervoltage Protection Flowchart

3.3.2.3. Energy Consumption Control

When a specific apartment exceeds the Current Limit set by the building administrator, the microcontroller will issue a sound alert for 10 seconds. If the tenant did not turn off the extra devices, the microcontroller will turn off the apartment's power relay, and will check again after 15 seconds.

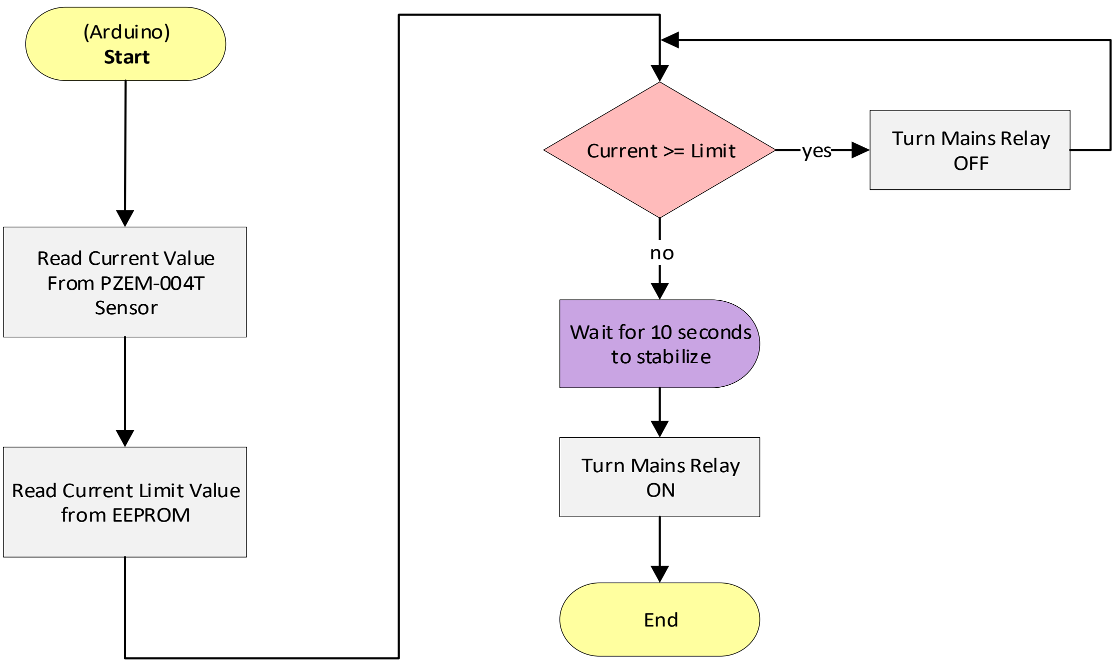


Figure 3-7 Over-Current Protection Flowchart

3.3.2.4. Outdoor Light Control Using Ambient Light Sensing

The ambient light sensor (photocell) senses the daytime light intensity and changes its resistance. The microcontroller senses the resistance value and therefore decides whether it's day or night time based on a pre-programmed value, then it turns on or off the outdoor lights. The user is also able to manually control the operation from the touch screen.

3.3.2.5. Fire and Gas Detection and Alert System

The BMU will receive its environmental sensors readings such as (gas sensor, temperature and humidity sensor, flame sensor, motion sensor, etc…) from the inter-connected AMUs that are installed in each apartment, and will reflect the reading on the BMUs touch screen and raise the alarm in case of any abnormality in the sensors readings.

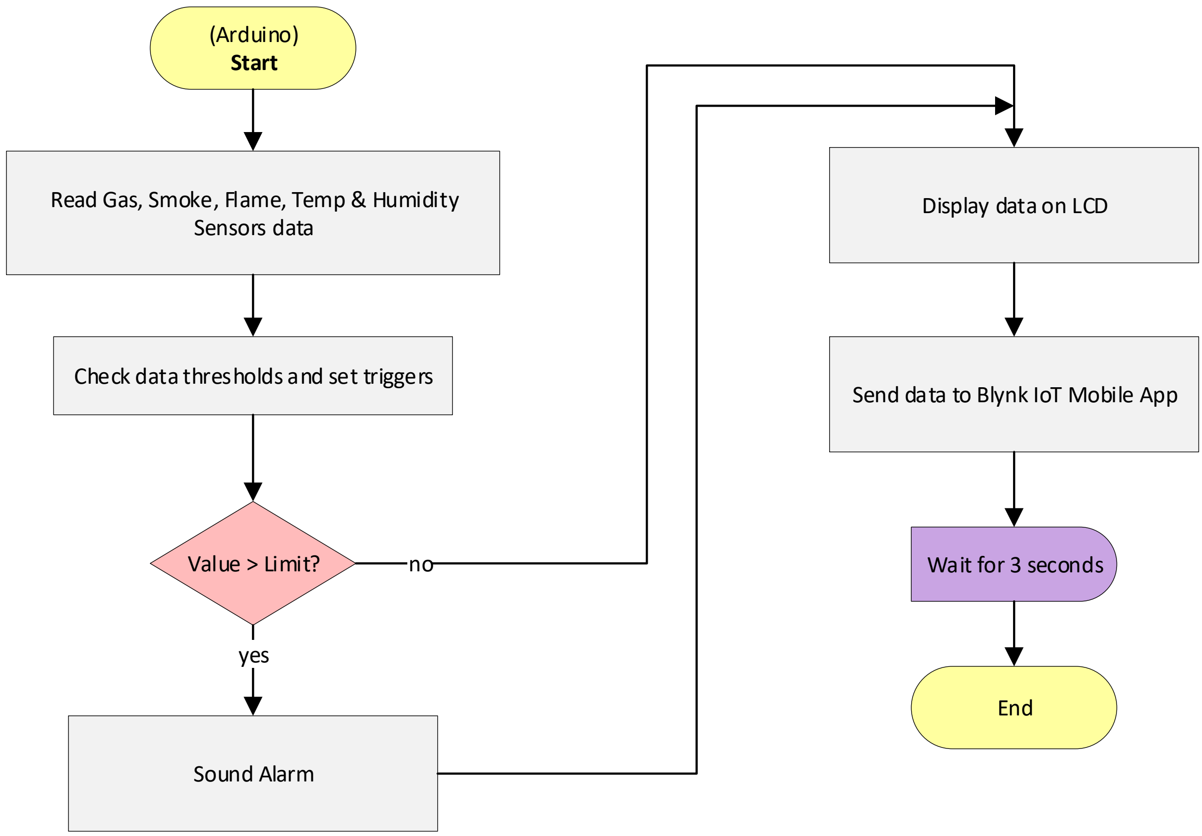


Figure 3-8 Temp, Humidity, Fire & Gas Sensors Monitoring Flowchart

3.3.2.6. Energy Cost Estimation

Through the Graphical User Interface on the Nextion touch screen, the user can estimate the monthly bill of cost for energy consumption based on a specified amount of current in Ampere unit using the integrated Cost Calculator.

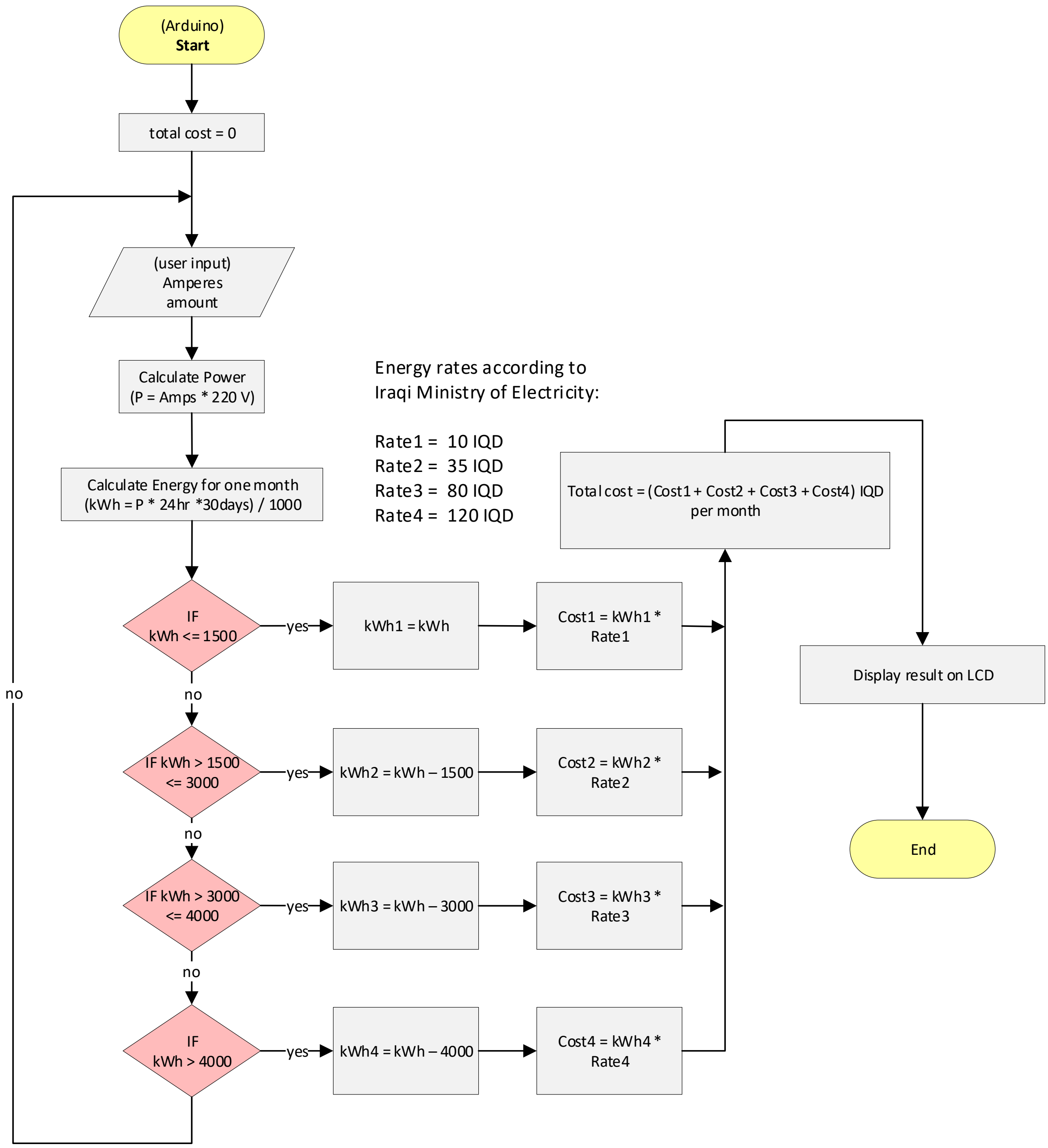


Figure 3-9 Energy Cost Calculator Flowchart

3.3.2.7. Blynk IoT Mobile Application Monitor and Control

The building manager can easily remotely monitor the power consumption and alerts of the BMU over the internet using special Blynk IoT Mobile Application. Also, it is possible to control the Mains line for each apartment separately.

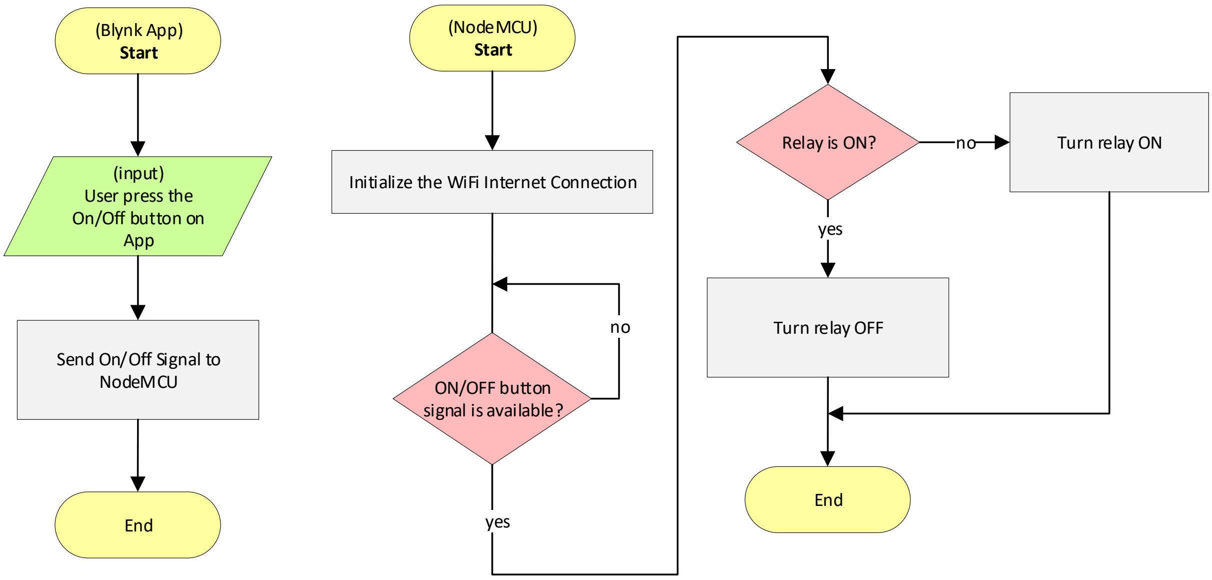


Figure 3-10 Relay Control Flowchart Using Blynk IoT Mobile App

3.3.3. <u>Apartment Management Unit Methodology</u>

The AMU can work either as a standalone (separated) device, or in conjunction with the BMU using the NodeMCU ESP8266 WiFi Microcontroller.

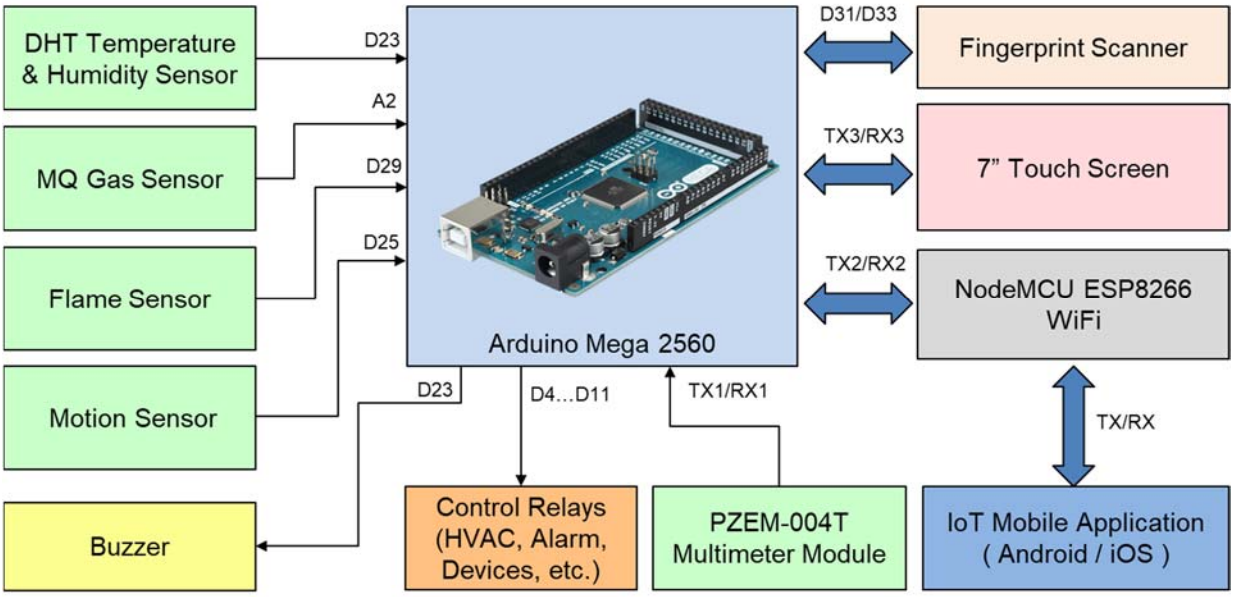


Figure 3-11 Apartment Management Unit - Functional Diagram

3.3.3.1. Power Measurement and Control

Each AMU has a dedicated and integrated Smart Meter System build on the PZEM-004T Multimeter module, that transmits the power readings to the microcontroller via the UART Serial Port. The microcontroller will then display the data on the touch screen, send it to Blynk IoT mobile app as well as to the BMU. The BMU will monitor the AMUs in case of over-current consumption and will issue back a Turn-Off or Turn-On signal based on the integrated algorithm.

3.3.3.2. Electrical Appliances Control

The tenant is able to control the electrical appliances of the apartment through the Control Menu of the AMU's touch screen. When a button is touched on the screen, the LCD will send a pre-programmed instruction to the Arduino microcontroller. The Arduino microcontroller then will respond to the instruction and turns the desired device On or Off.

3.3.3.3. Fire and Gas Detection and Alert System

The DHT temperature and humidity sensor, MQ gas sensor and the Flame Sensor, all work in coordination to ensure complete safety and accurate fire and gas sensing system. In case of a sensor detects an abnormality, the microcontroller will alert the apartment's tenant via the AMU, also will alert the buildings administrator via the BMU in the power control room.

3.3.3.4. Security

An Optical Fingerprint Scanner is used to protect the apartment tenant against unauthorized access, and provide an added layer of security. When the tenant scans his fingerprint, the scanner will transmit the fingerprint image data to the microcontroller, and then the image will be compared against the pre-stored tenant data to decide whether he/she is an authorized person or not. In case of a match, the microcontroller will open the door lock, and display a notification on the AMU's touch screen.

3.3.3.5. Energy Consumption Reduction

The motion sensor is used as a power consumption reducing solution. It works independently but it is also connected to the microcontroller. In case of any movement in walkways or preferred locations, the lights will turn on for 30 seconds. If there is no more movement, the lights will turn off. Same cycle repeats when any movement occur.

3.4. Design of The Graphical User Interface (GUI)

3.4.1. Building Management Unit

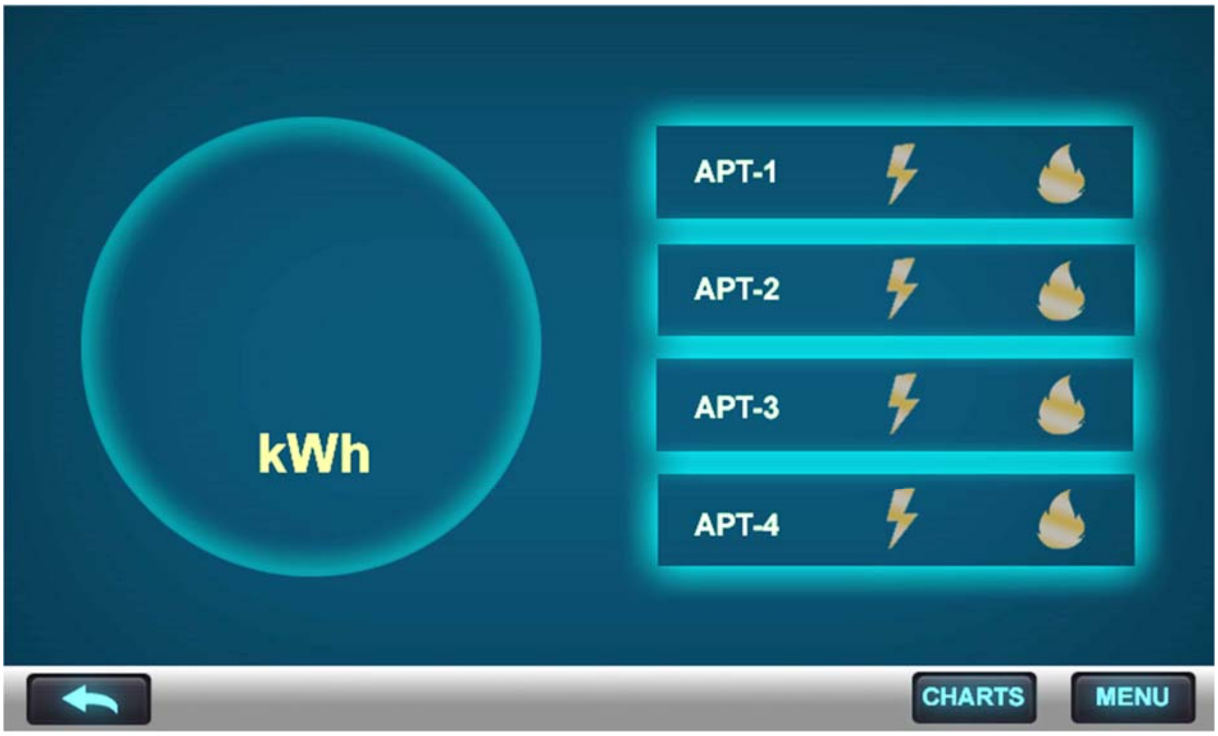


Figure 3-12 BMU Touch Screen GUI - Main Page

Figure 3-13 BMU Touch Screen GUI – Control Menu

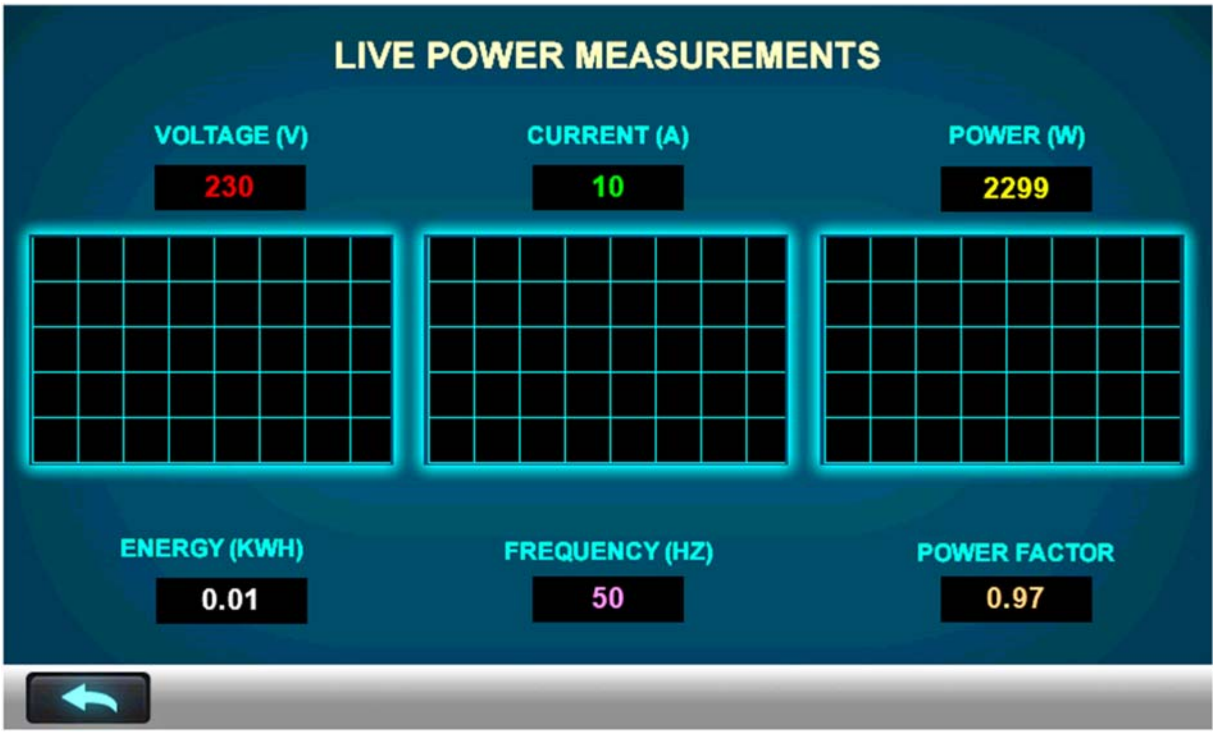


Figure 3-14 BMU Touch Screen GUI – Power Line Measurement Charts

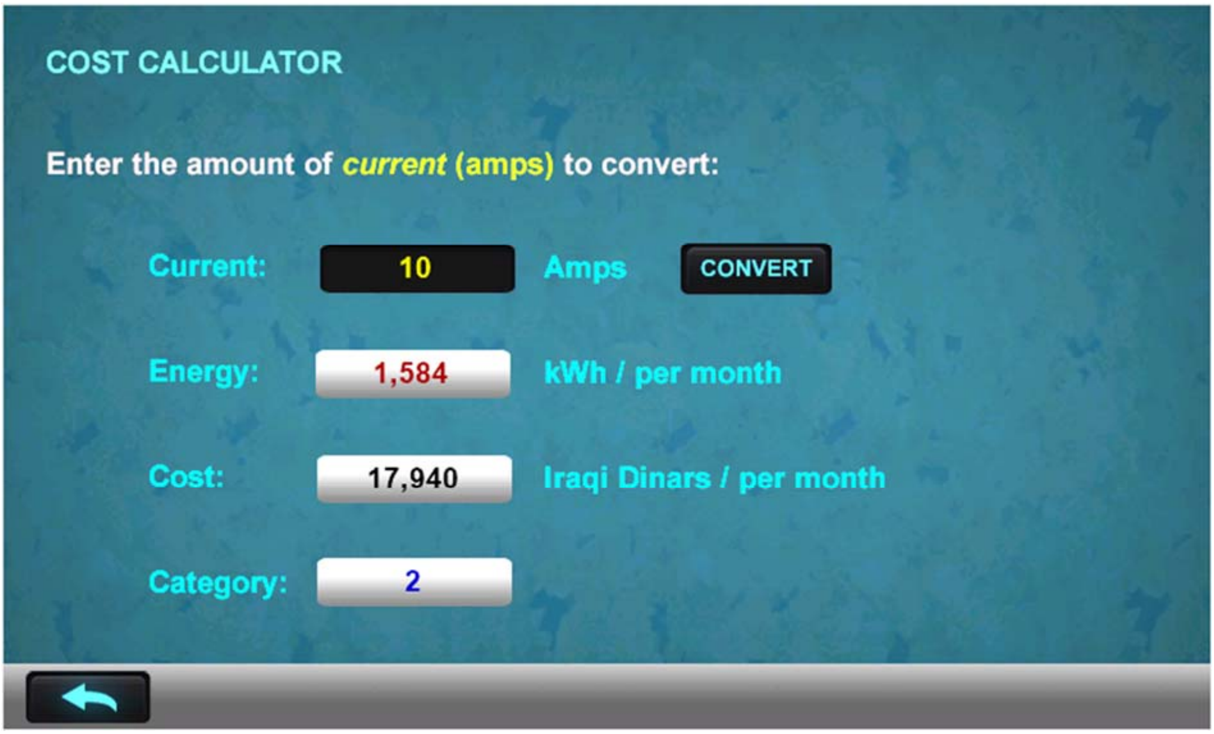


Figure 3-15 BMU Touch Screen GUI – Cost Calculator

Figure 3-16 BMU Touch Screen GUI – Lights Control

Figure 3-17 BMU Touch Screen GUI – Power and Light Control Sub Menu

3.4.2. Apartment Management Unit

Figure 3-18 AMU Touch Screen GUI – Main Menu

Figure 3-19 AMU Touch Screen GUI – Control Menu

Figure 3-20 AMU Touch Screen GUI – Security Alert

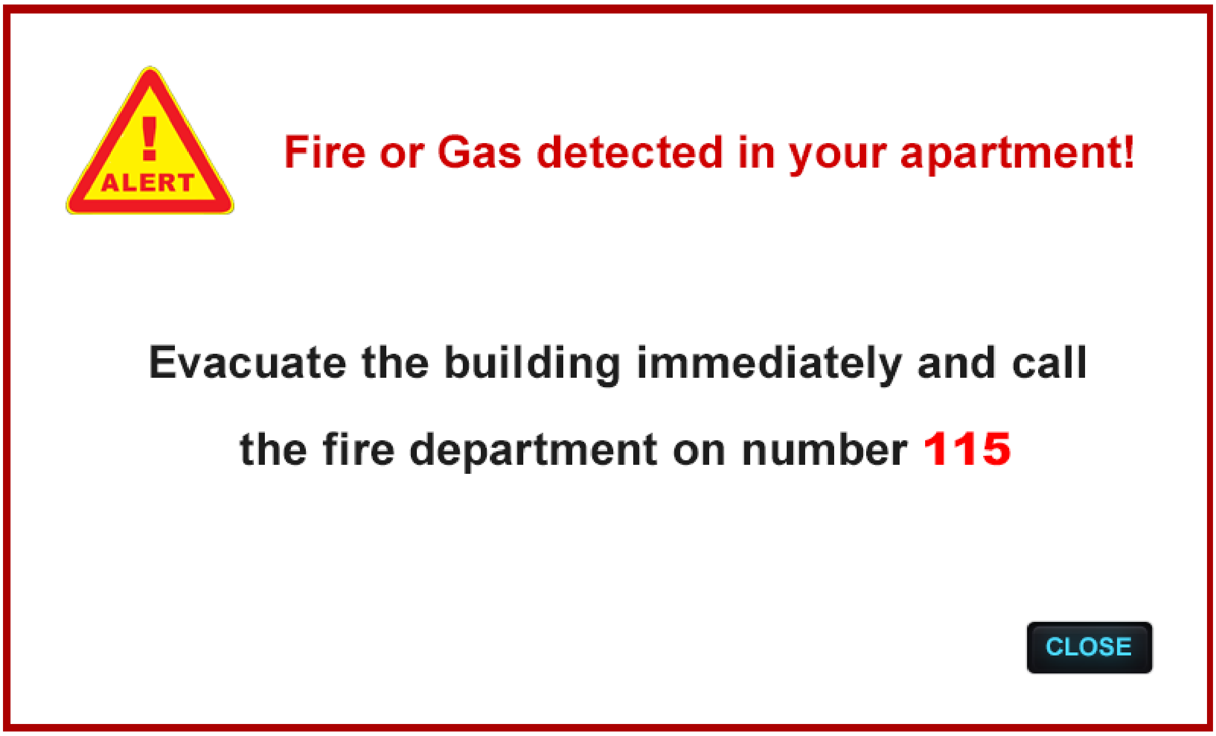


Figure 3-21 AMU Touch Screen GUI – Fire and Gas Alert

3.4.3. Blynk IoT Mobile Application

The figure below shows the Graphical User Interface (GUI) of the mobile application for the Smart Building Management Unit. It shows various options to monitor and control the building's power distribution system.

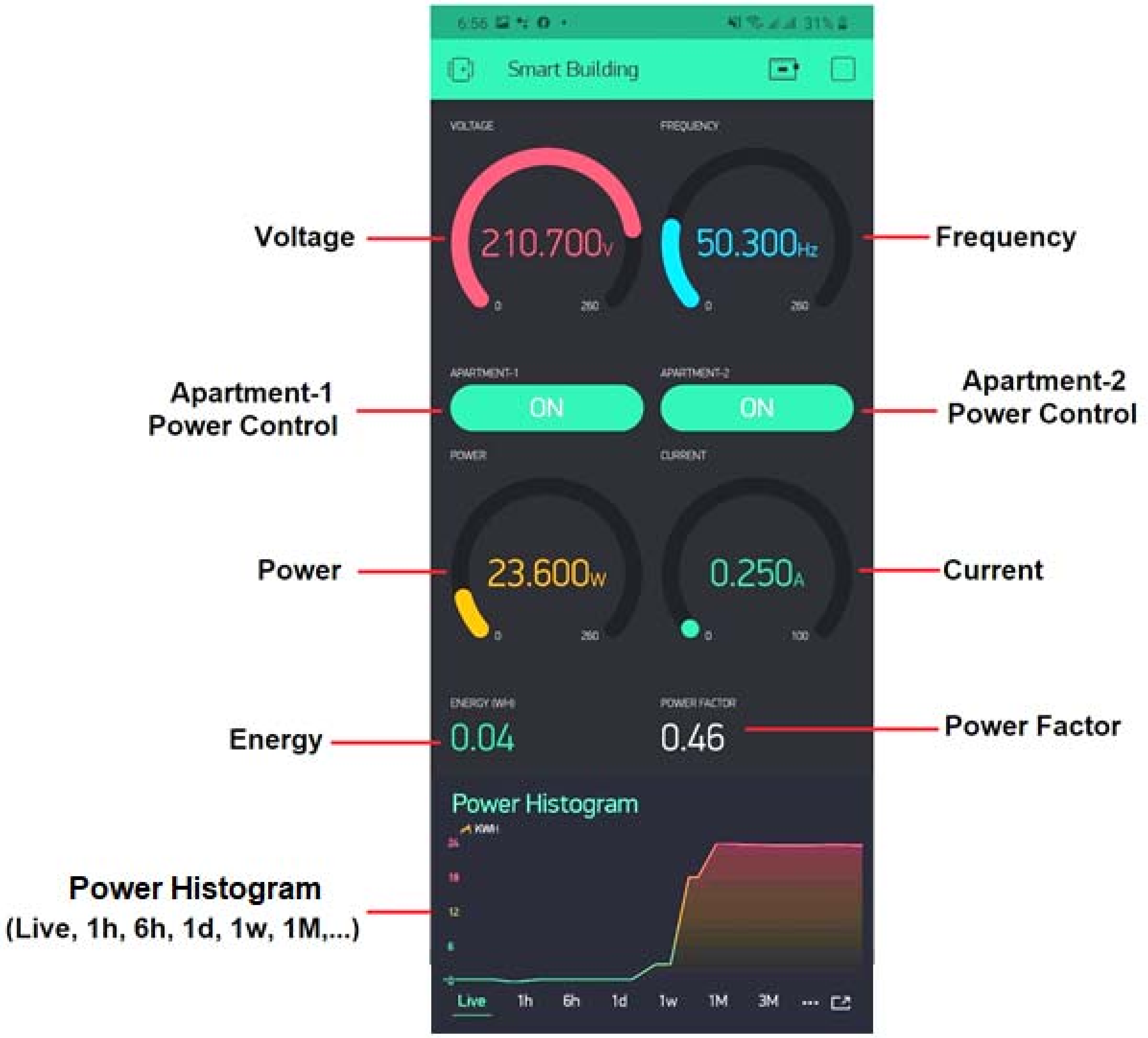


Figure 3-22 GUI of BMU IoT Mobile Application

A special mobile application was also designed and implemented for the Smart Apartment Management Unit, in order to enable the building occupants monitor and control their unique apartments using the Blynk IoT platform.

Figure below shows the power and temperature monitoring items, as well as the power control buttons for controlling different electrical appliances.

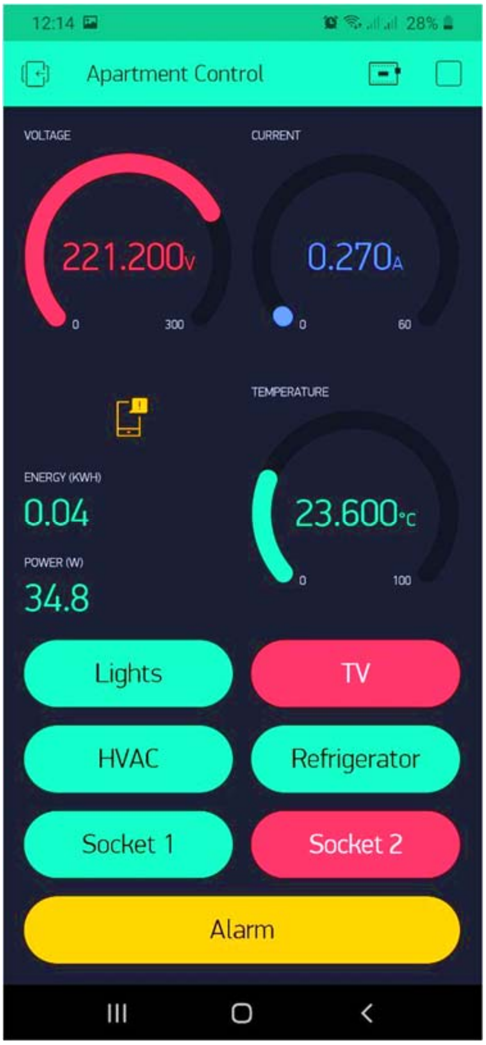


Figure 3-23 GUI of AMU IoT Mobile Application

3.5. Photographs of the Actual System Prototype

Figure 3-24 Prototype – External View

Figure 3-25 Prototype – Display Parts

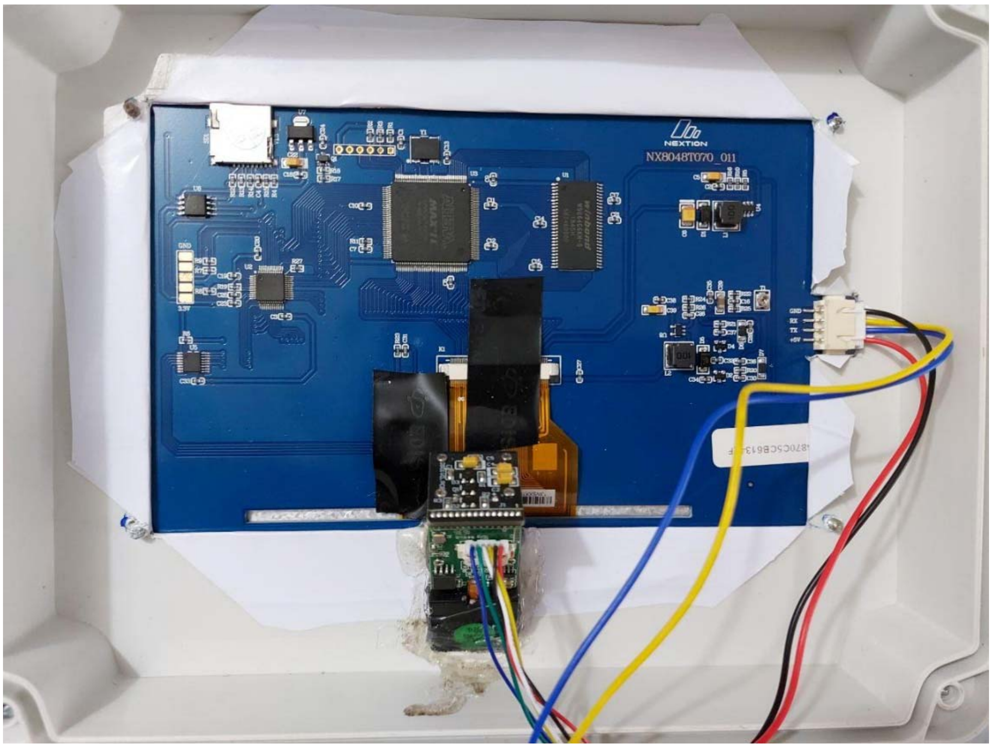


Figure 3-26 Prototype – Display Internals

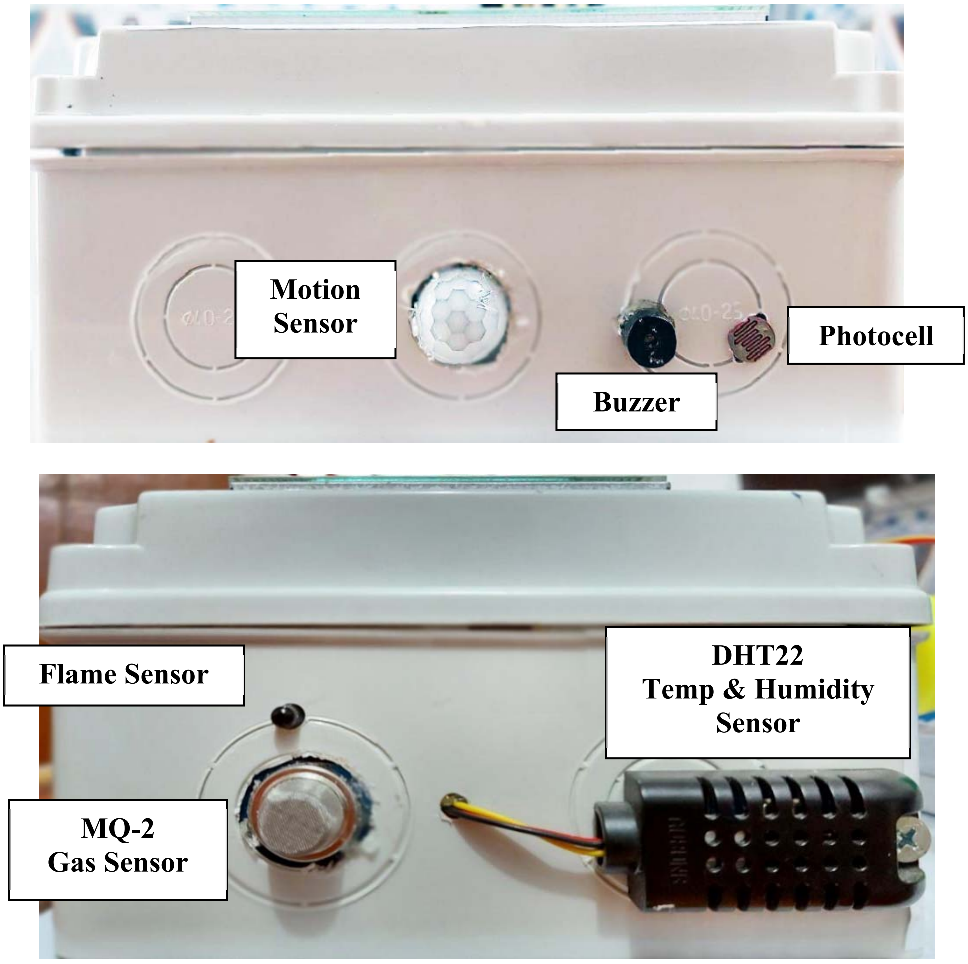


Figure 3-27 Prototype – Sideview Components

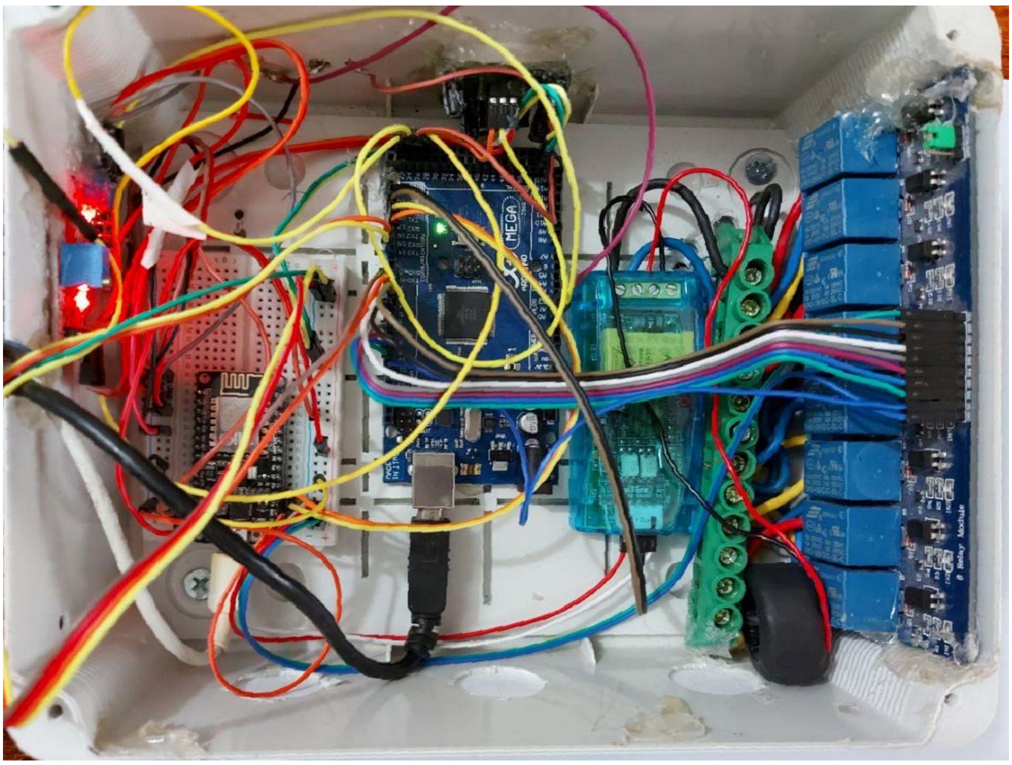


Figure 3-28 Prototype – Internal Hardware Components

CHAPTER FOUR

RESULTS OF IMPLEMENTATIONS FOR THE PRACTICAL DESIGN

Chapter Four

Results of Implementations for the Practical Design

4.1. Introduction

This chapter describes in details the results of the proposed system design and implementation in graphical and statistical forms.

The testing of both, the Building Management Unit and Apartment Management Unit proved a fully operative system that met the design aims and expectations, with a fast response to user commands and hardware state changes.

4.2. Results of Implementation

4.2.1. Power Monitoring System

The PZEM-004T Multimeter Module readings were compared against a fair priced hand-held multimeter device reading in the same time, focusing on the Voltage and Current values as presented in Table 4-1 below:

Table 4-1 Practical Comparison of Voltage and Current Measurement

Reading Type	PZEM-004T	Multimeter	Error Rate
Voltage	209.31 V	211.6 V	1.08%
Current	3.26 A	3.3 A	1.21%

The power measurements sample below were recorded in 5 minutes interval for different types of electrical appliances detailed in Table 4-2 below:

Table 4-2 Home Appliances Power Measurements

Device	Voltage	Current	Power	Power Factor
LCD TV	216.80	0.24	23.91	0.45
Air Cooler	216.30	1.17	213.82	0.85
Mini Air Cooler	214.70	0.74	145.40	0.92
Refrigerator	216.40	1.31	220.54	0.80
Oven (2 heaters)	212.20	6.43	1365.61	1.00
Juice Mixer	215.70	1.57	332.42	0.99
LED Light	215.70	0.24	42.50	0.82
Ceiling Fan	216.10	0.99	188.27	0.86
Laptop Charger	216.10	0.27	59.20	0.89
Internet UPS	215.30	0.37	50.30	0.63

As a complementary illustration, the graphs below show the difference in readings for the selected set of home appliances:

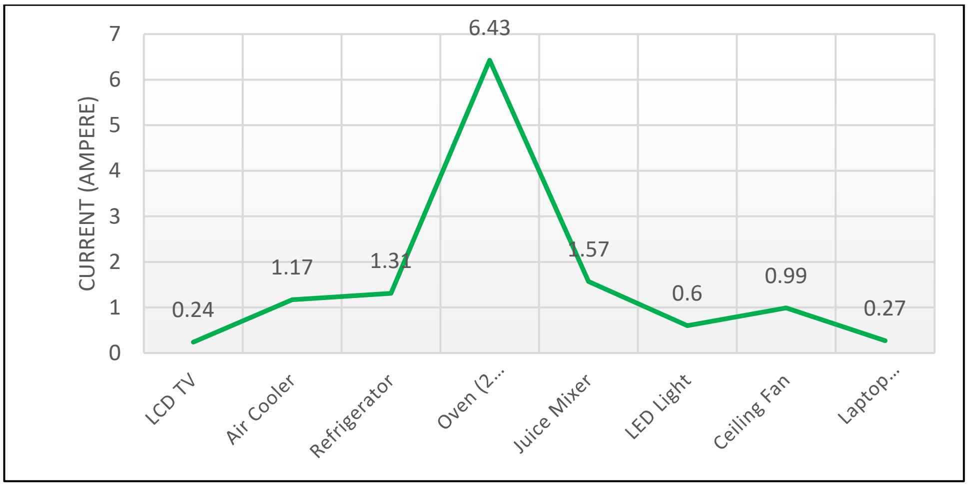


Figure 4-1 Current Consumption for Electrical Appliances

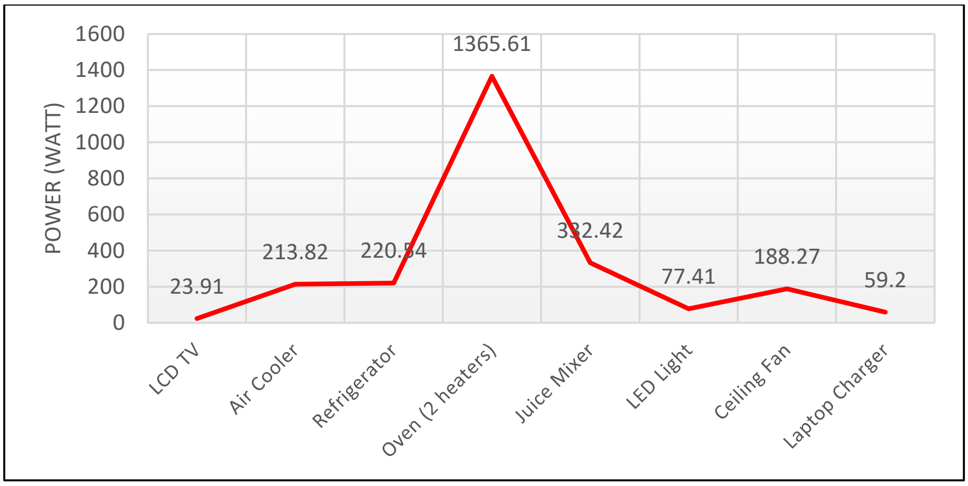


Figure 4-2 Power Consumption for Electrical Appliances

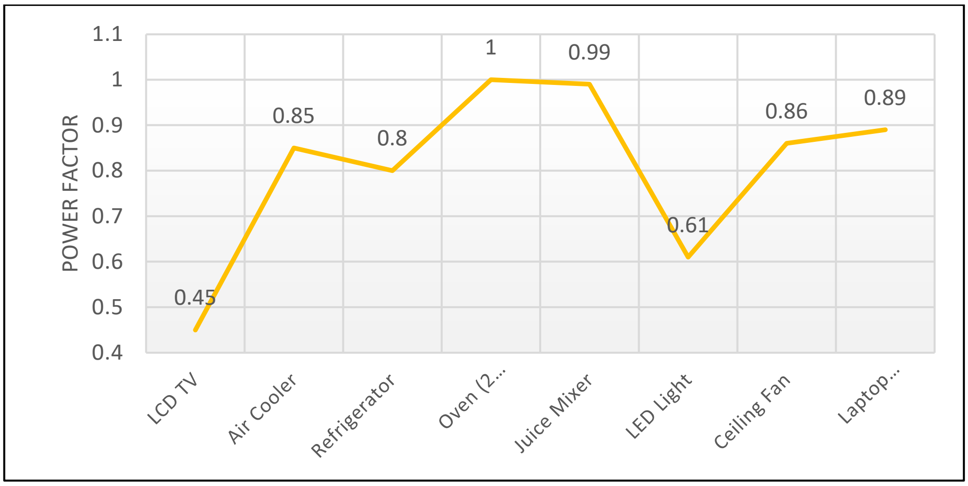


Figure 4-3 Power Factor for Electrical Appliances

Multiple data points where measured for the power monitoring system in order to provide a time series analysis based on actual data. The testing scenario was done on a selected set of devices with a different running configuration in order to make an intended change of readings in 30 minutes time roof. Table 4-4 below is a continuation to Table 4-3, which in conjunction will provide a comprehensive understanding of the power consumption for each data point (time).

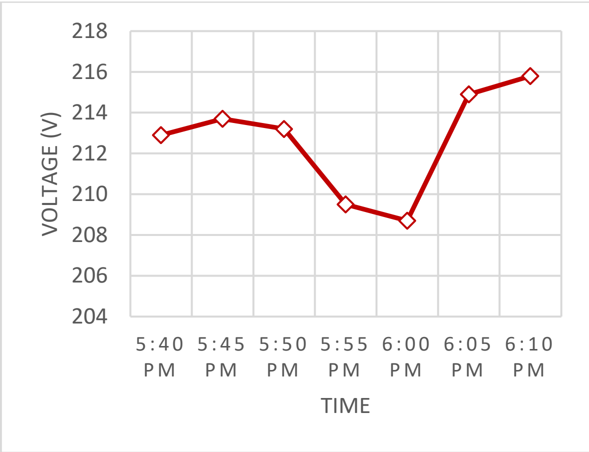
Table 4-3 Home Appliances Running Scenarios vs. Time

Time	LCD	Air Cooler	Mini Air Cooler	Refrigerator	Oven	Mixer	LED Light	Ceiling Fan	Laptop Charger	Internet UPS
05:40 PM		1	1	1			1	1	1	1
05:45 PM		1	1	1			2	1	1	1
05:50 PM	1		1	1			3	1	1	1
05:55 PM	1		1	1			3		1	1
06:00 PM	1		1	1	1		3		1	1
06:05 PM	1		1	1	1	1	3		1	1
06:10 PM	1		1	1			4		1	1

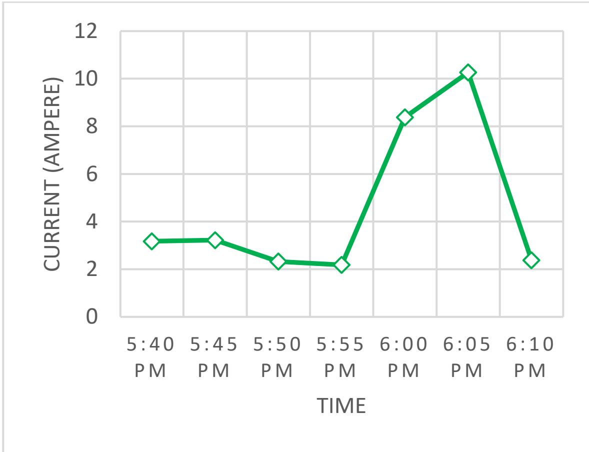
Table 4-4 Home Appliances Power Measurements vs. Time

Time	Voltage	Current	Power	Energy	Frequency	pF
05:40 PM	212.90	3.17	647.50	0.13	50.50	0.96
05:45 PM	213.70	3.22	654.60	0.19	50.60	0.95
05:50 PM	213.20	2.32	471.00	0.24	50.40	0.95
05:55 PM	209.50	2.18	426.00	0.28	50.10	0.93
06:00 PM	208.70	8.38	1740.50	0.32	50.10	1.00
06:05 PM	214.90	10.27	2175.90	0.48	50.20	0.99
06:10 PM	215.80	2.38	462.80	0.51	50.20	0.91

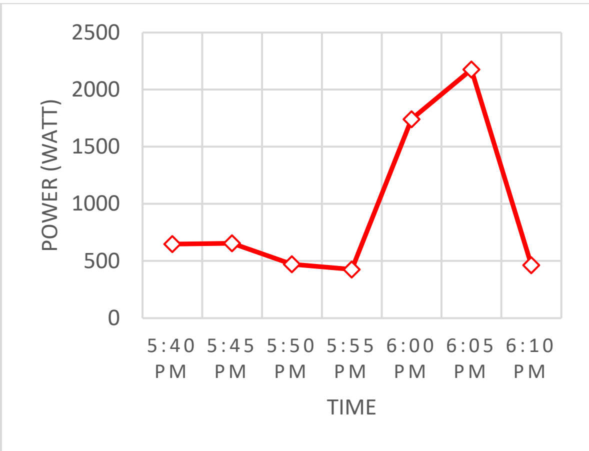
The graphs below show the power measurements changes in 30 minutes of test:



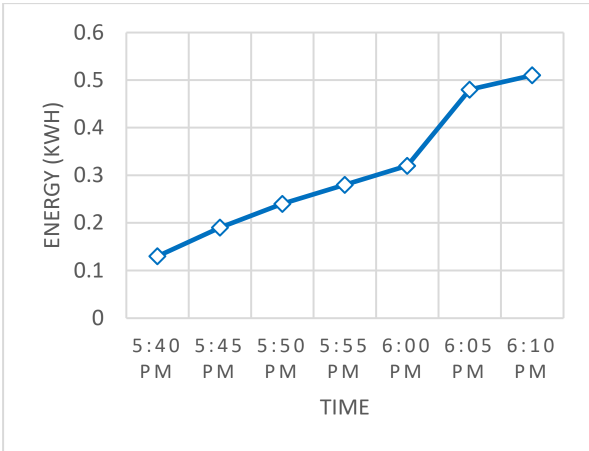
4-4a Voltage



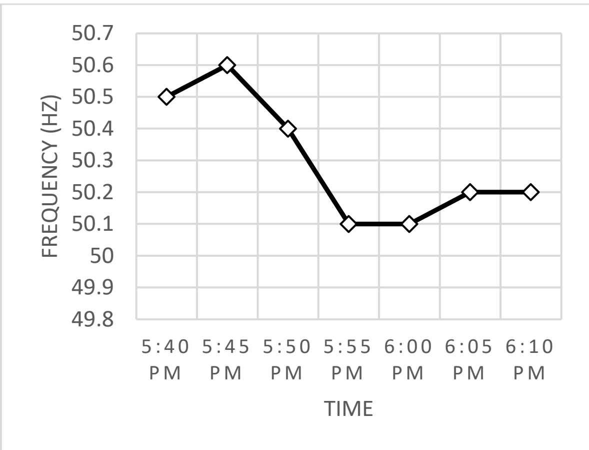
4-4b Current



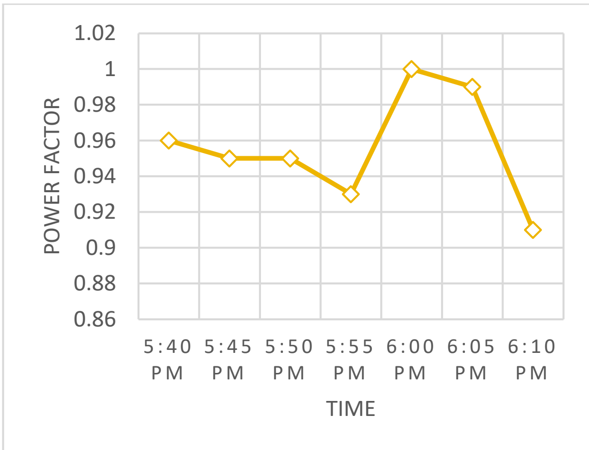
4-4c Power



4-4d Energy



4-4e Frequency



4-4f Power Factor

Figure 4-4 Time Series Analysis Graphs for Power Measurements

Figure 4-5 below shows the actual display of power measurements on the Nextion 7” Touch Screen for the Building Management Unit.

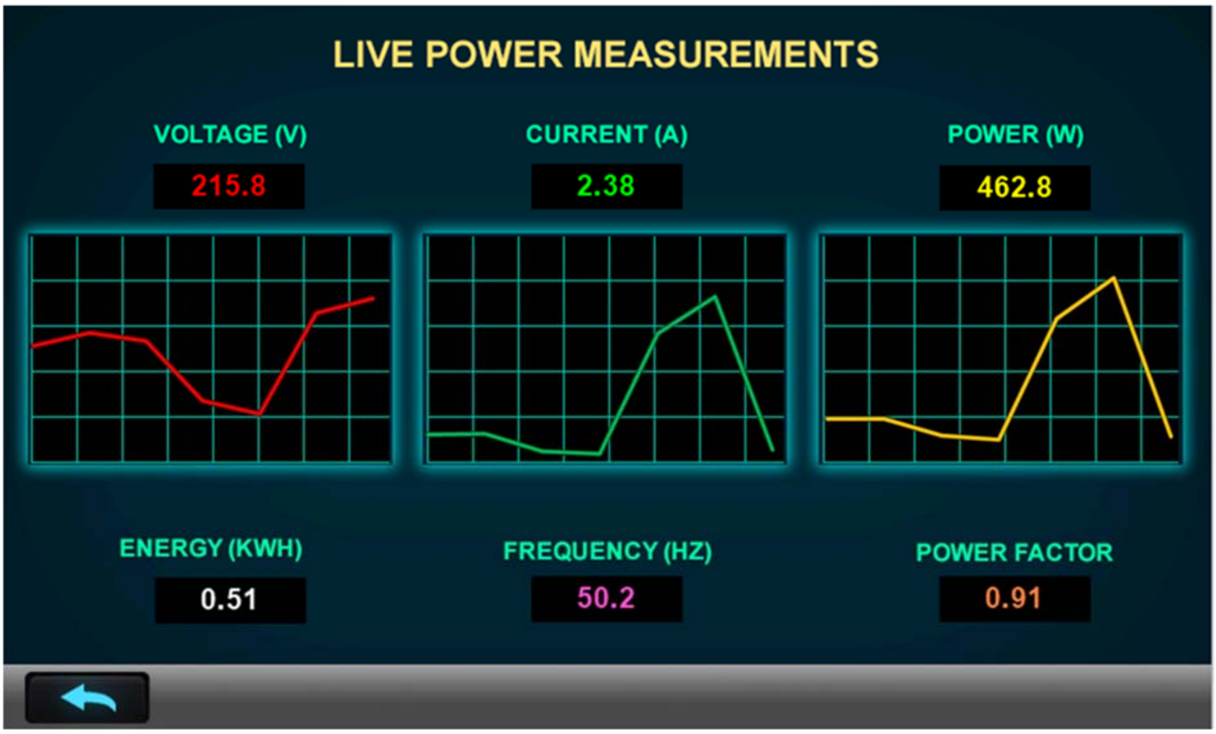


Figure 4-5 BMU - Actual Display of Power Measurement Data

Also, Figure 4-6 below shows the actual display of power measurements on the Nextion 7” Touch Screen for the Apartment Management Unit.

Figure 4-6 AMU - Actual Display of Power Measurement Data

4.2.2. Fire & Gas Monitoring and Alarm System

Seven sample data points were recorded for the fire & gas monitoring sensors (indoor) during 30 minutes of daytime, represented by the DHT22 Temperature & Humidity Sensor, and the MQ-2 Gas Sensor.

The sensors were intentionally exposed to smoke and fire in order to test the system response in case of gas leak, smoke or fire, as shown in data point labelled (10:45 AM) of the Table 4-4 below, which indicated a raise in readings, and the Alarm buzzer was also turned ON automatically. Also Figures 4-7 to Figure 4-10 provide charts of the testing time series.

Table 4-5 Indoor Fire & Gas Sensors Readings

Time	DHT22		MQ-2	
	Temp (C)	Humidity (%)	CO (ppm)	LPG (ppm)
10:30 AM	24.30	34.60	0.01	0.00
10:35 AM	24.50	33.70	0.00	59.20
10:40 AM	24.40	31.90	0.00	7.30
10:45 AM	24.30	32.60	0.00	0.00
10:50 AM	24.60	32.10	0.01	0.00
10:55 AM	26.90	22.50	0.22	0.00
11:00 AM	24.20	31.30	0.09	0.00

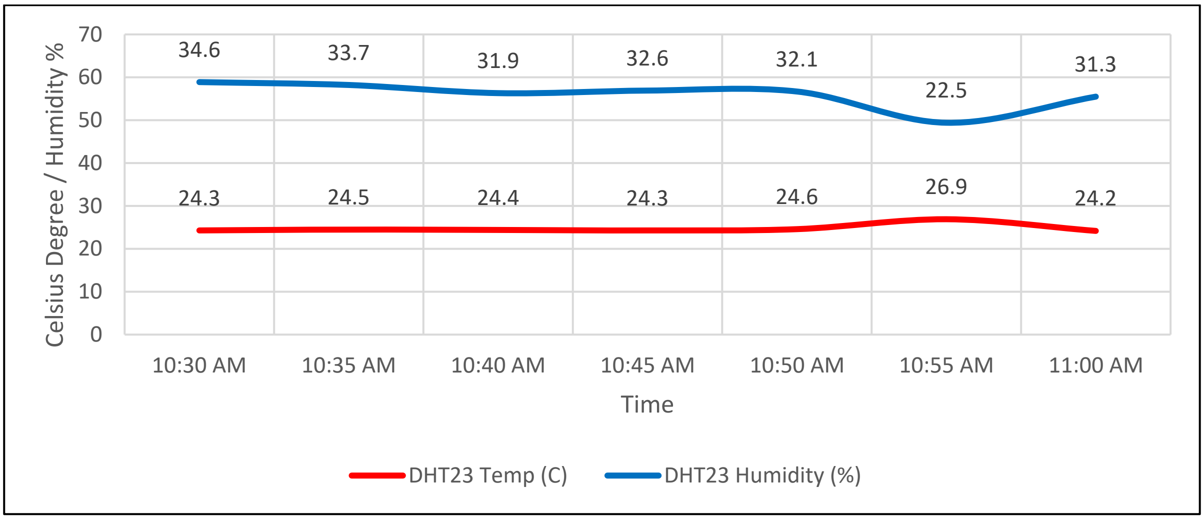


Figure 4-7 Temperature & Humidity Measurements

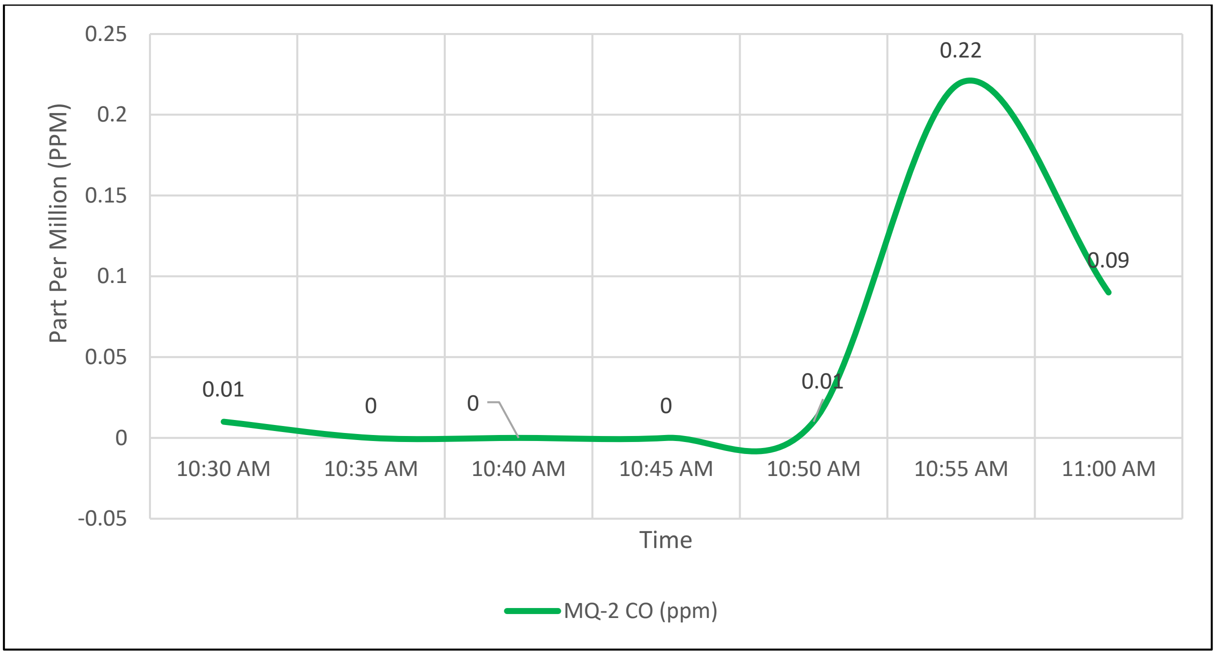


Figure 4-8 CO Gas – Smoke Detection on 10:55 AM

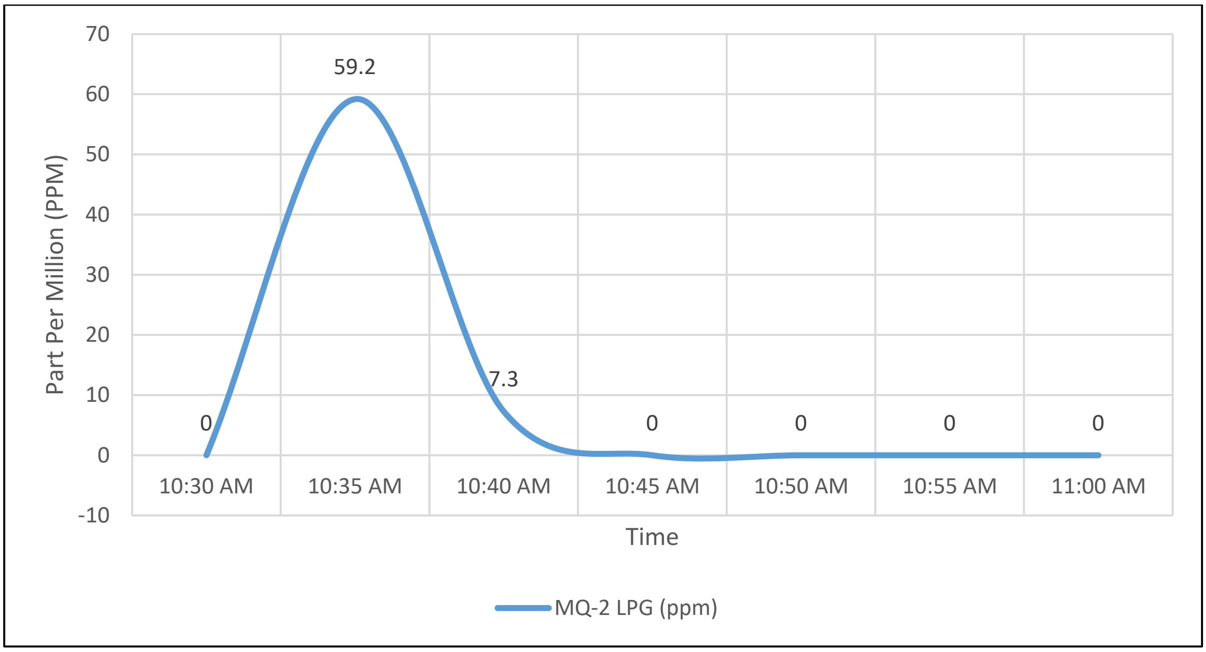


Figure 4-9 LPG Gas Leak on 10:35 AM

Also, when the Flame Sensor was exposed to fire, it has detected the fire and started the Alarm Buzzer immediately, as well as the status were updated on the Graphical User Interface for both the Building Management Unit (Figure 4-10)

and Apartment Management Unit (Figure 4-11), which proved a functioning and reliable fire monitoring system.

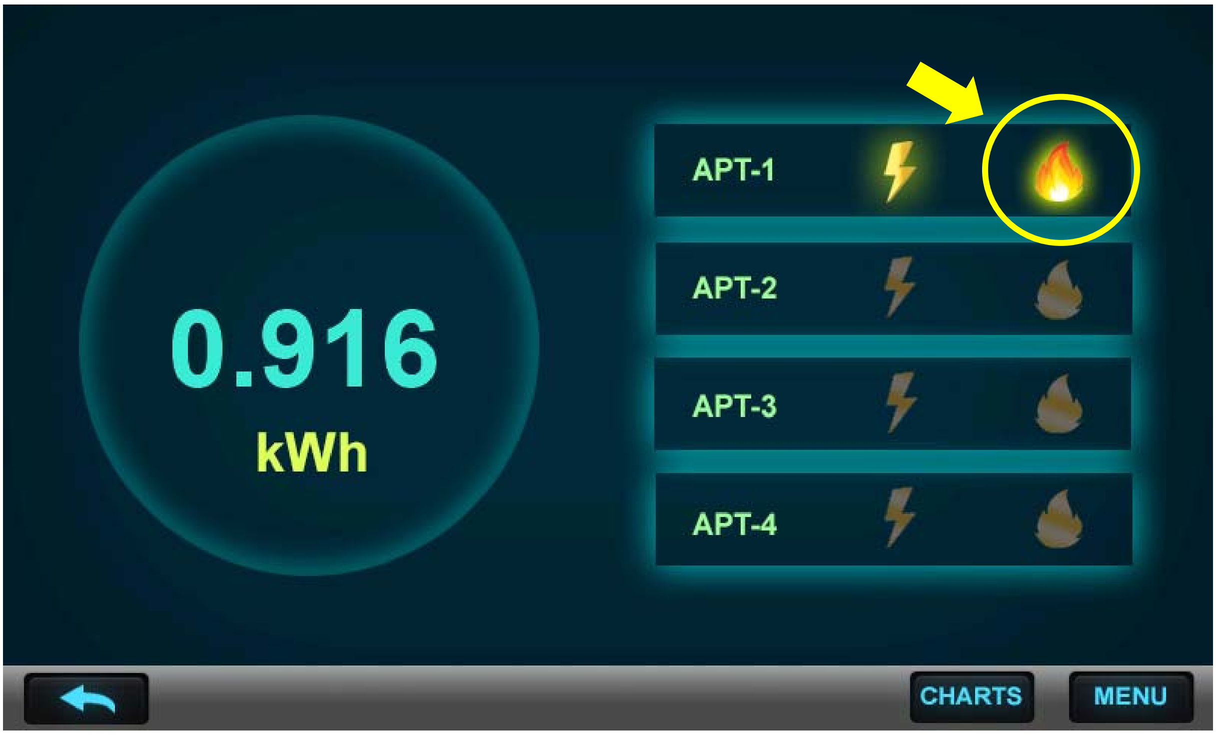
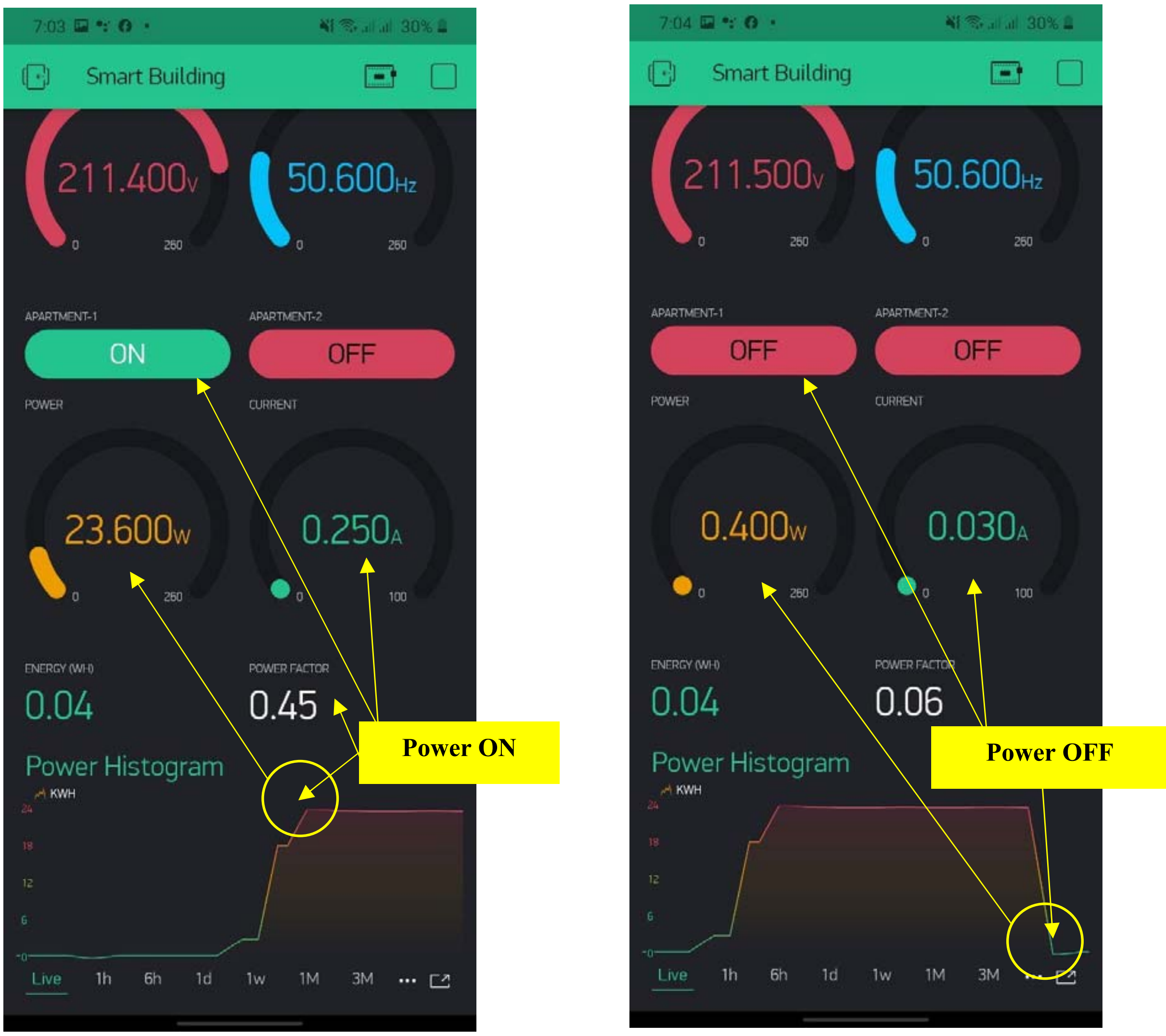


Figure 4-10 BMU – Fire Alarm Display

Figure 4-11 AMU – Fire Alarm, Temperature & Humidity Display

4.2.3. Blynk IoT Mobile Application

As a result of the implementation of Internet of Things technology in this project, represented by the Mobile Application of the Blynk IoT Platform, we were able to remotely monitor the Building Management System power measurements and power histogram over the internet from anywhere in the world in real-time. Also, were able to remotely control the Mains Power Feed for the suggested apartment of the building (Apartment-1) using the mobile application, as shown in the figure below.



Apartment-1 Power ON **Apartment-1 Power OFF**

Figure 4-12 Apartment Power Control using BMU Blynk IoT Mobile Application

On the other hand, and using the Apartment Management mobile application, we were able to remotely monitor and control the power and alarms of the system.

Figure 4-13 below shows different readings for the voltage, current, energy, power and temperature, as well as it shows different devices in ON and OFF state.

Also shows the Notification received when an event is triggered, such as gas leak detection, fire detection or security intrusion

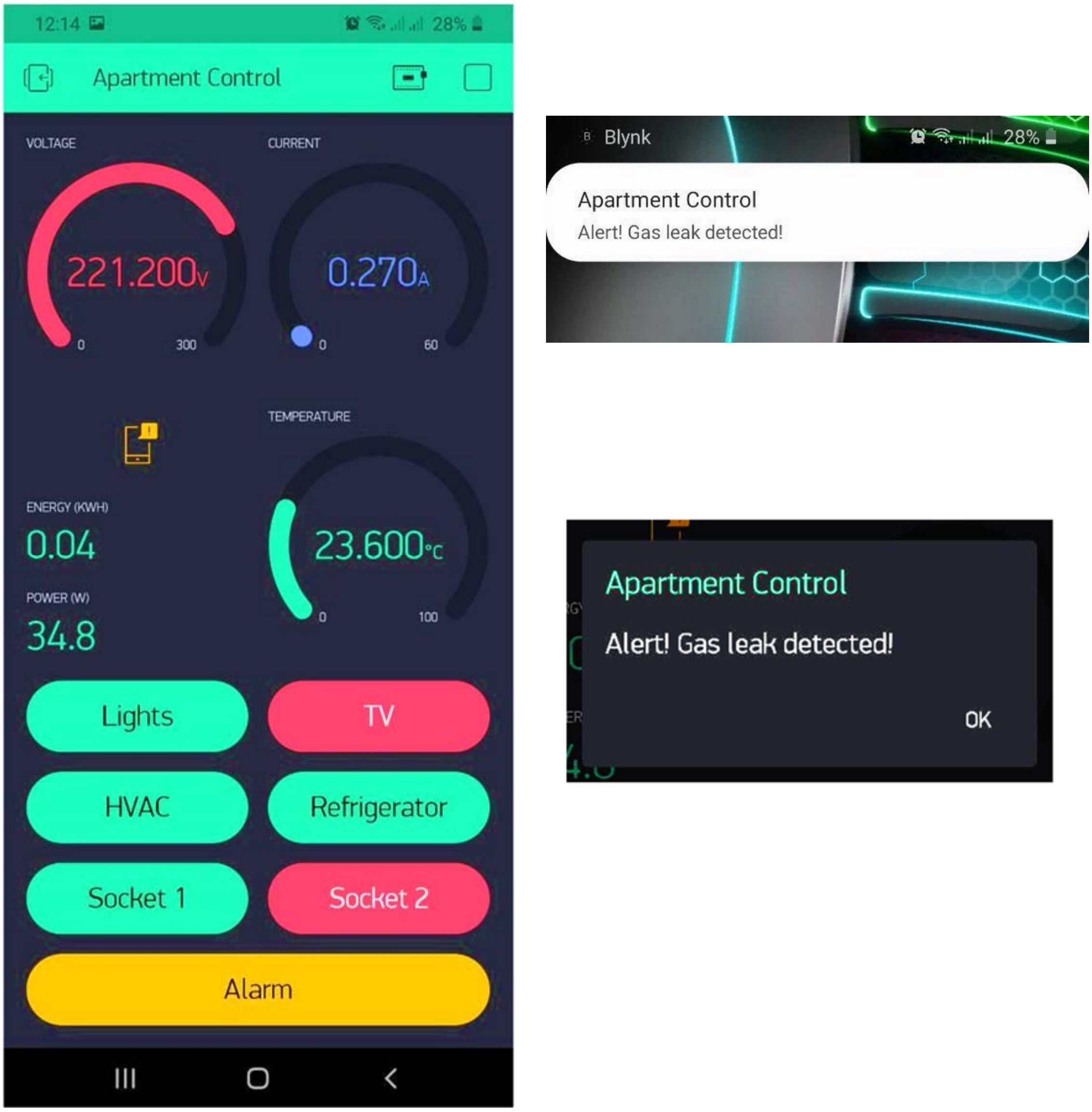


Figure 4-13 AMU Mobile Notification

4.2.4. Cost Estimation for Monthly Energy Consumption

The implementation of software algorithm for the Cost Calculator has proved accuracy in cost estimation and power consumption categorization. The figure below shows the calculator in-action on the BMU touch screen:

Figure 4-14 BMS – Cost Calculator Screen

CHAPTER FIVE

CONCLUSIONS, DISCUSSION AND FUTURE WORK SUGGESTIONS

Chapter Five
Conclusions, Discussion and Future Work Suggestions

5.1. Introduction

This chapter presents the observed conclusions from the designed system, discusses the difference between typical buildings and integrated buildings, future expectations for smart buildings and outlines future proposals for the system.

5.2. Conclusions

This project describes the details about design and implementation of intelligent building automation system. In this system, a novel architecture for low cost and flexible building control and monitoring system using Touch Screens, and any type of Smart phone, is proposed and implemented. A building manager can monitor and control the overall building via the Building Management Unit, and an occupant can monitor and control his\her individual apartment via the Apartment Management Unit. In addition, any Android or iOS based Smart phone with built in support for Wi-Fi and/or 3G connection can be used to access and control the devices at home.

In conclusion, we can state that based on the requirement of this project, smart buildings require control system design that involves a detailed study of different devices and their operation methods. First, we designed a sequence of operation for each part of the system (i.e. power measurement, overvoltage & undervoltage control, fire & gas detection, etc.). Then, we choose the required controller type based on the number of Inputs & Outputs that were put in the design, as well as the types of sensors, relays, touch screen, etc. After hardware selection, we drew the wiring diagrams using (Fritzing) software for its easy and elegant designs. The wiring diagram illustrated the way of connecting each device to the Microcontroller, such as sensors and relays. The system requires an active internet connection in order to enable it's IoT features to be monitored and controlled remotely using Mobile App. However, it can still work normally, centralized or standalone, using the associated 7" touch screen.

5.3. Discussion

Typical building Vs Integrated Buildings.

1) *Typical Buildings with no integration* have different segments to control the entire building. All segments, which are Fire Management System, Door Access and Intrusion Detection, Lighting Control System, HVAC Control System and Main Electrical/Power distribution system, are controlled individually. In this system, there is no link between two systems. The building control locally using computer as an interface. There is no interaction with Humans as system operates individually and locally. In case of emergency, one system cannot pass the signal to the other system to react. No integration is involved to interact the system to one another.
2) *In fully integrated Building*, all systems are connected on a common platform to interact with each other. Finally, entire system has two interfaces to control, monitor and feedback (Building Management Unit and Apartment Management Unit). The end user whether occupant or operator can interact with the system. End user interact with the system and the system respond to the end user's request. [35]

Smart buildings based on IoT concepts are expected to evolve rapidly in the next years. IoT is expected to enhance the functionality, capabilities, energy efficiency, and cost-effectiveness of buildings, moving up the automation continuum to a “smart building” status. Therefore, stakeholders should investigate evolving technologies such a next generation BMS, IoT, cloud services, and converged networks to get a better handle on the issue, save expenses on the bottom line, and future-proof their environments and their investments. In the face of some of the challenges faced by energy management of smart buildings based on IoT-centered systems, there are significant industry and technical opportunities. The desire to reduce energy costs both by the building owners and the tenants, as well by the energy suppliers looking to cut peak-rate consumption and construction of peaking power plants, along with the optimization of comfort

levels for office users and residents for both temperature and lighting conditions, affords this industry a strong business opportunity. From a technology perspective, the development of appropriate architectures and supporting standards, such that both equipment cost-effectiveness and interoperability will be beneficial.

5.4. Future Work Suggestions

Prospective future works include adding a specialized server unit to host and oversee all building activities, and to work as a more sophisticated alarm system that works on Artificial Intelligence and perform various machine learning tasks.

Instead of using the ready-to-use Blynk IoT Platform, the mobile application could be designed from scratch using native mobile application development languages, such as Java, Kotlin, Swift, Flutter, etc., in order to specifically fit the needs of this project and provide more stability and independence.

A datacenter could be built specifically for the purpose of Smart Building Management Systems, that can monitor and control multiple buildings in the same time, which is an introduction to the Smart City concept.

Another option could be incorporating SMS and call alerts, and reducing wiring changes for installing the proposed system in pre-existing buildings by creating a wireless network within the building environment to control and monitor the smart building environment. As it connects devices to smart plug switches as well as creating several building moods at specific times that are compatible for updating, such as opening and closing curtains, control lighting levels and colors, listening to music, etc.

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الخلاصــة

أصبحت أنظمة إدارة المباني الذكية أكثر تقدمًا ، ويتم تطوير مستوى التكامل تدريجيًا من مستوى النظام الفرعي إلى تكامل المباني وتقارب نظم المعلومات. تمثل الطاقة المستخدمة في المباني جزءًا كبيرً ا من استهلاك الطاقة العالمي ويقضي البشر معظم الوقت في الداخل. باستخدام أنظمة متكاملة وذكية ، من الممكن تحقيق تخفيض كبير في تكاليف صيانة المباني واستهلاك الطاقة مما يوفر بيئة معيشية أكثر راحة في نفس الوقت .

حاولنا في هذا المشروع تلبية الحد الأدنى من المتطلبات لإنشاء نظام إدارة مباني ذكي موثوق ومنخفض التكلفة.

للإجابة على الأسئلة ، قدمنا طريقتين للتشغيل ، أولًا وحدة إدارة المبنى التي تمكن مدير المبنى من مراقبة ومراقبة توزيع الطاقة الكلية واستهلاك المبنى ، بالإضافة إلى إدارة تنبيهات الحريق والغاز ، وثانياً وحدة إدارة الشقة التي توفر لشاغليها جهاز تحكم مركزي لإدارة الطاقة وتنبيهات الحريق والغاز ، ودرجة الحرارة والرطوبة ، بالإضافة إلى التحكم في الأجهزة الكهربائية مثل)التلفزيون ، الثلاجة ، التدفئة والتهوية وتكييف الهواء ، وما إلى ذلك(. تم أيضًا تصميم تطبيقين للهاتف الجوال ، تطبيق لكل وحدة ادارة ، وذلك باستخدام منصة Blynk لانترنت الاشياء ، حيث يغطي التطبيقان نفس الوظيفة ويتيح لكل من مدير البناء والمقيمين إدارة وحداتهم عن بُعد عبر اتصال إنترنت WiFiأو3G .

أظهرت نتائجنا تنفيذًا واعدًا وموثوقًا للتكنولوجيا المستخدمة مع استجابة سريعة ودقيقة للغاية. أثبتت شاشة اللمس وتطبيق الهاتف المحمول أنها حلول جيدة لهذا النوع من المشاريع ، بالإضافة إلى مكونات الأجهزة والبرامج وأساليب الاتصال التي تم اختيارها في تصميم المشروع .

الإهـــــ داء

الى الشمعه التي احترقت لتنير الدرب

الى مثلي الاعلى الى روح

أبـــي

الى من زرعتني في الحياة بذرة

وسقتني من دمها قطرة بعد قطرة

أمـي

الى من ساندني ووقف بجانبي

زوجي وأولادي

الى من ساعدني بإنجاز مشروعي

أخـي زياد

الى من علمني وعرفني طرق العلم

بكل محبة الى مربي الاجيال العظماء

الذين لن أنسى فضلهم يوما

أساتذتـي الكرام

جمهورية العراق
وزارة التعليم العالي والبحث العلمي
الجامعة التكنولوجية
قسم الهندسة الكهربائية

تصميم وبرمجة وتنفيذ نظام إدارة المباني الذكية باستخدام تقنية انترنت الأشياء

مشروع مقدم إلى

قسم الهندسة الكهربائية / الجامعة التكنولوجية
كجـزء من متطلبات نيل شـــهادة البكالوريوس في الهندسة الكهربائية
فرع الهندسة الالكترونية

من قبل الطالبة
شذى هاني جاسم

إشراف
الاستاذ المساعد صباح عبد الحسن القره غولي

2020